ERRATA.

Jour. Roy. Soc., Western Australia, Vol. XI.

p. 2 *for* **Pseudomonotis echinata** (J. Sow.) *read* **Pseudomonotis** cf. **echinata** (J. Sow.).

p. 5 line 17, p. 10 line 24, p. 12 line 6, *for* Aalemian *read* Aalenian.

p. 10 line 8 *for* belemnite *read* belemnites.

Plate I. figs. 6a and 6b are upside down.

Journal

OF

The Royal Society of Western Australia.

Vol. XI.

1924-1925.

The Authors of Papers are alone responsible for the statements and the opinions expressed therein.

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1925.

THE ROYAL SOCIETY OF WESTERN AUSTRALIA.

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VICE PATRON: HIS EXCELLENCY SIR WILLIAM CAMPION, K.C.M.G.

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LIST OF MEMBERS.*

As at July 1st, 1925.

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*Members are requested to notify the Hon. Secretary for Physical Science of any change of address.

LIST OF MEMBERS—*continued.*

Honorary Members—continued.

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Wood, W. E., Inspecting Engineer's Office, Railway Department, Perth.
Wright, A. R. L., L.R.I.B.A., Public Works Department, Perth.

Student Members:

1924.

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Williams, F. A.

1925.

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Andrews, Miss E.
Builder, G.
Burnell, Miss M.
Carrigg, C. G.
Finucane, K. J.
Forman, F. G.
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McMeikan, Miss A.
Mosey, W.
Owen, E. C.
Parr, Miss M.
Tonkin, Miss E.
Wood, F. W.

ANNUAL REPORT OF THE COUNCIL FOR THE YEAR ENDING 30th JUNE, 1925.

Ladies and Gentlemen,—

Your Council begs to submit the following report for the year ending 30th June, 1925: —

Membership: As from 1st July, there are 262 members on the roll, of whom 8 are honorary members, 4 corresponding members, 161 ordinary members, 72 associate members, and 17 student members.

During the year 13 ordinary members and 13 associate members have been elected, while 11 ordinary members and 4 associate members have resigned. In addition, the names of 7 ordinary members and 2 associate members have been removed from the roll in accordance with Rules 10 or 12.

Dr. Hancock has been elected to honorary membership, and Mr. D. A. Herbert to corresponding membership in the Society. Messrs. A. O. Neville and A. R. Galbraith have been transferred to associate membership.

The Council records with regret the deaths of Miss M. Dwyer, associate member, and Mr. J. Neilson and Associate Professor Tomlinson, ordinary members of the Society.

Vice-Patron: The position of Vice-Patron, rendered vacant by the departure of Sir Francis Newdegate, has been accepted by the new Governor, His Excellency Sir William Campion, K.C.M.G.

Finances: Although the Council has been able so far to meet this year's routine expenses (consisting for the major part of the cost of publication of papers for Volume XI), yet the finances of the Society are by no means on a satisfactory footing.

A deputation to the Government, while meeting with an entirely sympathetic reception, was unable to secure an annual Government grant, but it is hoped that the Government will later see its way clear to make some contribution towards the funds of the Society, particularly in view of the fact that this is the only Royal Society in Australia which does not receive financial aid from its State Government.

The Financial Statement shows a balance of just over £80, but of this sum it is estimated that at least £65 will be required to complete the publication of Volume XI. Further, a considerable expenditure on the Library is urgently necessary, both in the provision of more accommodation, and in the binding of sets of publications now in hand. In addition, a sum of money should be set aside for the preparation of a Library Catalogue, as otherwise many valuable papers received in exchange remain unknown or practically inaccessible to members.

Publications: The new scheme of publication referred to in last year's annual report has been in force throughout this session. It was decided that the current volume be issued in bound form to all members, but any member may, by paying member's price, obtain a separate copy of any particular pamphlet.

As expected, the cost of Volume X, issued under the new system, and containing 129 plus 28 pages, 11 plates, and 13 figures, amounted to less than £100. It is anticipated that the cost of Volume XI will be about the same.

Several valuable papers relating to Western Australian matters have been received from non-members. It is felt that the Society is fulfilling its aim of furthering the cause of science by publishing these.

Reports of Committees: (1) As no faith-healing sessions have been held in Perth during the year, the Committee on Spiritual Healing has been unable to add anything to the interim report published last year. This report must therefore be taken as final.

(2) A report from the Committee on "Salinity in Soils" is appended.

Exchange of Papers: Negotiations are at present under way through the medium of the Local Secretary of the Institute of Physics (Professor Ross) for the interchange among Australian Royal Societies of original papers in Mathematics and Physics immediately after being read. This will result in workers in these branches of science being brought more closely into touch throughout Australia, and it is hoped that the system may eventually be extended to papers in natural science.

Australasian Association for the Advancement of Science: It is a matter for gratification to Western Australia generally that the Australasian Association for the Advancement of Science has decided to hold the next meeting in Perth in August, 1926. Members will be pleased to know that the invitation to the Conference to meet here next year was seconded by our President as a delegate from this Society.

Institute of Science and Industry: At the conference held in Melbourne recently to discuss the re-organisation of the Institute of Science and Industry, Professor Ross was appointed one of the two delegates to represent the interests of Western Australia.

Dr. W. J. Hancock: Your Council, together with representatives of other scientific societies, has for some time past been endeavouring to secure adequate recognition of the services to science of Dr. W. J. Hancock, Gold Medallist and Honorary Member of this Society. It is therefore pleasing to know that the Federal Government has granted to Dr. Hancock the sum of £1000, while the pension provided by the Government of this State has been substantially increased.

Council: There have been 12 meetings of the Council held during the year, the attendance being as follows: The President (Professor Ross) 9, Mrs. Shelton 12, Miss Allum 10, Miss Creeth 1, Miss Milner 6, Miss Reed 3, Professor Nicholls 6, Dr. Simpson 5, Messrs. Allum 12, Carne 10, Clarke 7, Gibb Maitland 7, Grasby 7, Montgomery 10, Phillips 10, Saw 6, Shelton 6, and Thompson 12.

The vacancy on the Council due to the resignation of Miss Reed was filled by the appointment of Miss Creeth.

Thanks: The thanks of the Society are due to Mr. W. M. Carne, who has been acting as Joint Hon. Secretary during the absence in England of Mr. W. E. Shelton; and also to Miss D. F. Milner, who is not seeking re-election, for her services in connection with the Library.

(Signed) A. D. ROSS,
President.

R. D. THOMPSON,
Joint Hon. Secretary.

REPORT OF SPECIAL COMMITTEE ON SALINITY IN SOILS.

(To 30th June, 1925.)

Two meetings of the Committee have been held, one in November last and one in April. A third one was arranged tentatively for this week but had to be postponed owing to my compulsory absence from Perth.

During the year just ended a fair amount has been done in the way of obtaining information through kindred bodies in the Eastern States, and when the Government Geologists and Water Supply Engineers of the various States were in Perth last year the question was discussed with some of them. As a result of this, communication was opened with Mr. Lockhart Jack, Deputy Government Geologist of South Australia, who had given the matter much consideration in connection with the deposits of salt and gypsum in South Australia.

Mr. Jack kindly wrote very fully on some aspects of the question and also sent four Bulletins containing a great many data bearing thereon.

The Health Department of the Commonwealth had been interested for some time in determining the normal quantities of chlorine in ground water at various places in Australia, and had asked the Commonwealth Meteorologist to assist them in discovering what quantities of chlorine were borne inland in rain. As we were interested in a very similar question, viz., the amount of salt being air borne, we joined forces and in March last arrangements were completed to take samples of rain under the same set of instructions at 32 widely distributed points in Australia. Those in Western Australia are: Perth, Condon, Mundiwindi Wiluna, Coolgardie, Esperance, Cue and Geraldton. Samples by mail are being franked by the Meteorological Department and free analyses made by the Government Analyst, Perth. The samples sent by rail are being free freighted by the Railway Department and analysed by the Railway Chemist free of cost to the Royal Society.

In addition to the tests outlined in the preceding paragraph another series is being conducted on rain water collected in rain gauges from which the accumulated dust from dry winds, etc., has not been removed. The Stations at which this series is being carried out are Mallewa, Merredin (State Farm), Wickepin, Mount Barker, and Mundaring.

It will take another nine months to complete the testing of rain, and it is hoped that the Committee will be in a position to present a report containing judgments on the subject matter of the enquiry by June, 1926.

W. E. WOOD,

Convener.

ROYAL SOCIETY OF WESTERN AUSTRALIA.

STATEMENT OF RECEIPTS AND EXPENDITURE FOR THE YEAR ENDED 30th JUNE.

RECEIPTS.

		£ s. d.	£ s. d.
Balance in hand on 1st July, 1924—			
In Bank—Medal Fund	33 18 6		
Ordinary Rev. ..	6 8 7		
		40 7 1	
In Cash		3 3 6	
			43 10 7
Subscriptions—			
1922-23		3 3 0	
1923-24		21 10 6	
1924-25		167 14 9	
1925-26		3 3 0	
Students' Fees		2 5 0	
			197 16 3
Medal Fund			18 10 6
Donation for Conversazione			1 0 0
For reprints from Journal, etc.			3 11 7
Interest on Banking Account			2 8 2
			£266 17 1

Note: In addition to the Expenditure shown in this Statement, a debt of about £65 for the balance of Vol. XI has been incurred. The accounts for this work had not been passed for payment by the 30th June, 1925.

EXPENDITURE.

		£ s. d.	£ s. d.
Printing Journal—			
Government Printer, Part of Vol. X		23 1 6	
R. S. Sampson, Binding Vol. X ..		3 17 6	
R. S. Sampson, Part of Vol. XI ..		29 6 6	
Art Photo Engravers, Part of Vol. XI		6 16 9	
			63 2 3
Card programmes, etc.			6 6 7
Paper, envelopes, etc.			5 9 6
Gold Medal			14 16 0
Die for Medal			33 16 3
Conversazione			10 18 2
Balance of launch hire			3 0 0
Petty cash, postages, etc.			27 12 3
Museum (fees for cleaning room, etc.)			13 16 0
			178 17 0
Balance on 30th June, 1925—			
In Bank—Medal Fund	3 16 9		
Ordinary Rev. ..	81 4 4		
		85 1 1	
In Cash		2 19 0	
			88 0 1
			£266 17 1

AUTHORS OF ADDRESSES AND ORIGINAL PAPERS DELIVERED DURING THE 1924-1925 SESSION.

Carne, W. M.—A preliminary census of the plant diseases of south-western Australia.

Cheel, Edwin—Notes on "blind grass" or candyup poison (*Stypandra imbricata* R. Br.) and certain other species that have been confused with it.

Chilton, C.—A freshwater crustacean from south western Australia.

Compton, G. Spencer -The British Empire exhibition.

Everson, D. W.—Construction and efficiency of crystal receiving sets in wireless telegraphy.

Gardner, C. A.—(1) Contribution to the flora of W.A., No. 4. (2) A list of the naturalised plants of extra-tropical Western Australia.

Glauert, L.—Australian Scorpionidea, Parts I, II, and III.

Hayman, W. G. —The transmission and reception of wireless telephony.

Herbert, D. A. Root parasitism of West Australian Santalaceae.

Holt, B. M. -Automatic fire sprinklers, thermostatic alarms, and their operation.

Knapp, A.—A note on the actinic value of light in Western Australia.

Mathews, W. H.—Life history of a cup moth.

Nicholls, G. E. -Two new terrestrial amphipods from Western Australia.

O'Dowd, M.—The physical causes of rain.

Reath, J. L.—Mollusca from the sub-recent beds of the lower Swan River district.

Ross, A. D.—(1) Applications of science in commerce and industry (Presidential address). (2) On the variation of light intensity in the solar corona, 1922, September, 21.

Whitehouse, F. W.—Some Jurassic fossils from Western Australia.

Withers, T. H.—The occurrence of *Uintacrinus* in Australia.

Some Jurassic fossils from Western Australia by F. W. Whitehouse, M.Sc.

Foundation Travelling Scholar, Department of Geology, University of Queensland. *Communicated by* E. de C. Clarke.

(*Read* October 14, 1924. *Published* November 20, 1924.)

The fossils described below form part of a collection (now lodged in the University of Sydney) made by Dr. W. G. Woolnough, at a locality east of Geraldton.* Though a small collection and, unfortunately, largely fragmentary, it is nevertheless a welcome addition to the Jurassic fauna of Australia, and affords some valuable evidence in considering the age of the deposit.

The fossils, which for the most part are in excellent preservation, occur in a yellowish to brownish matrix highly calcareous and with occasional quartz grains.

Description of the Species.

ECHINOIDEA.

Genus CIDARIS Leske.

Cidaris sp.

(Pl. I., figs. a, b.)

There is one cidarid spine, broken at the extremities, which differs in ornamentation from all forms known to the writer. The surface is covered with rows of regularly spaced hemispherical granules super-imposed upon a finely reticulate structure in micro-relief, the points of concurrence of the bars of the reticules bearing faint secondary granules.

No form can be quoted for adequate comparison.

BRYOZOA.

Genus BERENICEA Lamour.

Berenicea cf. **archiaci** Haime.

Attached to the guard of a belemnite there is a single specimen belonging to this genus, but which is not perfect enough for precise specific determination. The zoarium is discoid, zoecia visible for their whole length and peristomes slightly raised. No gonocysts appear on the specimen.

*The exact locality, communicated to me by Dr. Woolnough, is "The Nineteen Mile, a watering stop on the Geraldton-Cue Line, nineteen miles east of Geraldton." E. de C.C.

It is very like, and may perhaps be identical with *B. archiaci* Haime* which has been recorded in Europe from the middle Lias to the Oxfordian.

LAMELLIBRANCHIATA.

Genus PSEUDOMONOTIS Beyrich.

Pseudomonotis echinata (J. Sow.).

Pl. I., figs. 2 a, b, c.

1821. *Avicula echinata*, J. Sowerby, "Mineral Conchology," vol. 3, p. 75, pl. 243.
1870. *Avicula echinata*, Moore, Q. J. G. S., vol. XXVI., p. 232.
1878. *Avicula echinata*, Etheridge, Jr., Cat. Aust. Fossils, p. 10.
1910. *Avicula echinata* Glauert, Bull. West. Aust. Geol. Surv., No. 36, p. 100

This identification is based on a single specimen, but it is an excellently preserved left valve free from matrix. A very careful comparison was made between this specimen and a large suite of individuals from the Cornbrash of England. It is somewhat more circular in outline and has a more pronounced division of the ribs into primaries and secondaries than the *average* English form; but the variation of the species in the Callovian covers such forms as the present.

Unfortunately the range of the species in Europe has not been definitely established The holotype is from the lower Callovian (Cornbrash) and Rollier† would apparently restrict it to such an horizon. But it certainly extends through the Bathonian, being met with in the Forest Marble, great Oolite, etc. Under the name *Avicula braambariensis* Phill., Morris and Lycett figured two different Bajocian forms. An examination of the second of these specimens‡ has convinced the writer that it does not differ greatly from *P. echinata*. It may be differentiated perhaps by its larger size and the more prominent division of the ribs into primaries and secondaries (in this latter feature it resembles the Australian form). Further, there are "species" from higher horizons, e.g., *P. kiliani* Rollier§ from the Oxfordian, which are again very close to *P. echinata*. No doubt many of these similar Upper Jurassic forms represent a definite lineage, but the division into species at present is haphazard and very unsatisfactory. Until zonal work is done on the European forms it is not possible to allocate the present form with any precision. The writer believes that, when worked out, the vertical range of *P. echinata* may be rather extensive, and under that belief, would provisionally refer the Australian form to that species.

The hinge structure and muscle scar are well shown. These

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*See particularly J. W. Gregory: Catalogue of Jurassic Bryozoa (British Museum), vol. I, p. 97, pl. IV., figs. 1-3.

†Rollier: Fossiles Nouveaux ou peu connus, etc. (Mem. Soc. Pal. Suisse, Vol. XL., 1914, pt. 4), p. 411.

‡Morris and Lycett: Monograph of Mollusca from Great Oolite. (Pal. Soc.), pt. 2, 1853, p. 129, pl. XV., fig. 7.

§Rollier, loc. cit. p. 407, pl. 24, fig. 5.

features, however, appear to retain a uniform character throughout the Jurassic species.

A search made in the Moore Australian collection in the Bath Museum (England) has brought to light only one fragment of the species.

Genus OXYTOMA Meek.

Oxytoma decemcostata n. sp.

(Pl. I., fig. 3.)

1870. *Avicula munsteri*, Moore (non Bronn), Q.J.G.S., Vol. XXVI. p. 232.

1878. *Avicula munsteri*, Etheridge, Jr., Cat. Aust. Fossils, p. 107.

1910. *Avicula munsteri*, Glauert, Bull. West Aust. Geol. Surv., No. 36, p. 100.

Specific Characters:—Left valve very inequilateral, bialate, transversely elongate, produced posteriorly. Main part of the shell ornamented with ten radial costæ, the intercostal spaces being almost flat and adorned with about seven fine costulæ in each case. Costæ produced ventrally as short projecting spines. Growth-lines forming concave curves in intercostal spaces. The first six costæ from the anterior end curving anteriorly; the remaining four with a posterior curvature. Anterior wing ornamented with about five costæ; the posterior wing with costulæ only. Right valve unknown. Hinge line of the normal *Oxytoma* type.

Fig. 1.—Hinge Structure of *Oxytoma decemcostata* n. sp. (left valve). × 4.

Obs: In the opinion of the writer, *Oxytoma* (genotype *Avicula munsteri* Bronn) is sufficiently different from *Pteria* to be regarded as a separate genus rather than a subgenus according to general usage. As with so many of the Jurassic lamellibranchs the divisions of the genus are not well understood. There is, e.g., no information regarding the relation of the coarsely costate (e.g., *O. costata* J. Sow*) and the finely costate forms (e.g., *O. munsteri*† Bronn). The two types often occur together, but whether this indicates two separate lineages, repetition of coarsely costate forms from a finely costate stock or even a type of species dimorphism, has yet to be worked out. It may be noted in passing that, in the Moore collection from Western Australia, one coarsely costate *Oxytoma* and three finely costate forms similar to the holotype occur.

*J. Sowerby "Mineral Conchology," Vol. III. p. 77, pl. 244, fig. 1., lower figure.

†See Goldfuss "Petrefacta germanica," T. 2, 1836, pl. 118, fig. 2.

The delimitation of European species is not particularly definite. The specimens recorded by Moore as *A. munsteri* Bronn have been examined by the writer and are cospecific with the present specimen. The species differs from Bronn's type (as figured by Goldfuss*) mainly in possessing fewer ribs. It apparently belongs to the lineage of *O. munsteri* Bronn and *O. scarburgensis* Rolliert; for in shape and costal curvature it approaches closely to this assemblage. There are certain forms in the Jurassic, e.g., the lower Lias *O. sinemuriensis* (d'Orb.), which have 10 or 12 costæ, but no such form approaches particularly close in the other features. If comparison may be made with the coarsely costate forms, then *O. notabilis* Ter. et Joudy‡ and *O. costata* Sow are worthy of notice.

Genus TRIGONIA Bruguiere.

Trigonia moorei Lycett.

1870. *Trigonia Moorei* Lycett, Q.J.G.S., Vol. XXVI., p. 254, Pl. XIV., figs. 9, 10.

1877. *Trigonia Moorei* Lycett, British Fossil Trigoniæ (Pal. Soc.), p. 151 (text figure).

1878. *Trigonia Moorei* Etheridge Jr., Cat. Aust. Fossils, p. 113.

1903. *Trigonia Moorei* Chapman, Trans. Proc. Roy. Soc. Victoria, Vol. XVI. (n.s.), p. 327.

1904. *Trigonia Moorei* Etheridge Jr., Recs. Aust. Mus., Vol. 5, pt. 4, pl. XXVII., figs 3, 4.

1904. *Trigonia Moorei* Etheridge Jr., Bull. W. Aust. Geol. Surv., No. 36, p. 36, pl. IV.

1904. *Trigonia Moorei* Glauert, Bull. W. Aust. Geol. Surv. No. 36, p 101.

This species is very abundant in the collection both in the form of testiferous examples and internal casts all excellently preserved. There is a certain amount of variation within the species shown in the shape of the shell and the thickness of the ribs. The following table is an attempt to show the shape variation graphically, the measurement taken being indicated by the accompanying text-figure.

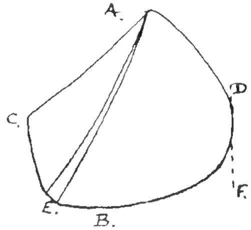


Fig. 2.—*Trigonia moorei.*

*The species was not figured by Bronn.

†Equivalent to the *Avicula munsteri?* of Morris and Lycett. (Pl. XIV., fig. 6.)

‡Terquem et Joudy: Monographie de l'Etage Bathonien. (Mem. Soc. Geol. France Ser. 2, vol. IX., 1869), p. 123, pl. XIII., figs. 9, 10.

SPECIMEN.	Valve.	CD.	100 AB. / CD.	100 EF. / CD	100 CE. / CD.
1. Holotype (Moore Coll.)	Right	48 mm.	95	80	56
2. Moore Coll. (fig. d. Lycett).	Left	61 ,,	103	87	52
3. Moore Coll.	Right	53 ,,	100	81	44
4. Moore Coll.	Left	46 ,,	96	86	54
5. Woolnough Coll.	Left	33 ,,	96	85	48
6. Woolnough Coll.	Left	30 ,,	98	88	56
7. Queensland Museum Coll.	Right	48 ,,	94	85	58
8. Queensland Museum Coll.	Left	51 ,,	101	83	51

The species has been carefully dealt with by various authors on former occasions; but further remarks on its affinities may not be out of place The presence of a sulcus instead of the median carina on the area renders the form distinct from most of the costate forms from England that have been figured by Lycett. Indeed only one of his specimens,* a rather unusual form of *T. costata* J. Sow. is comparable in this respect. Lycett regarded *T. costata*† as the species most similar to *T. moorei,* though he also remarks on the resemblance to *T. sculpta*‡ Lyc. In the opinion of the writer the latter species among English Trigoniæ is perhaps nearest to *T. moorei;* for in general dimensions and the intensity and curvature of the ribbing on the anterior portion of the shell the two show close agreement. The English form differs, however, in the coarseness of the areal ornamentation and the presence of the median carina. Both *T. costata* and *T. sculpta* are Inferior Oolite species, though the variety *rolandi* Cross, of the latter species ranges into the Cornbrash (Lower Callovian). The Aalemian species *T. alemanica* Rollier§ from Switzerland is closely comparable with *T. moorei,* the differences being mainly of shape. The Swiss form possesses very similar ornamentation; and in the condition of the ante-carinal sulcus, the presence of a median sulcus in place of a second carina and in the general ornamentation of the area it has a striking resemblance to the present species.

Dr. Kitchin, when dealing with the rich Trigonia fauna from Cutch (India), remarked at length upon the resemblance between *T. dhosaensis* Kitchin¶ and *T. moorei.* While admitting this similarity the author would suggest that *T. brevicostata*|| Kitchin and *T. distincta* Kitchin** are more akin to *T. Moorei* than the former species. All three are closely comparable in antecarinal

*Lycett, Monograph British Fossil Trigoniae (Palaeont. Soc., 1877), pl. 29, fig. 6.

†Lycett, loc. cit. (1870), p. 254 and 1877, p. 151.

‡Lycett, loc. cit. (1877), p. 159.

§Rollier, loc. cit., p. 65, pl. 6, fig. 6.

¶Kitchin, Jurassic Fauna of Cutch II. (1), Trigonia. (Pal. Indica ser. IX., vol. III.), p. 29, pl. III., figs. 1, 2.

||Kitchin, loc. cit., p. 23, pl. II., figs. 3, 4, 5.

**Kitchin, loc. cit., p. 25, pl. II., figs. 6, 7.

and post carinal ornamentation and in general dimensions. *T. dhosaensis* comes from the upper part of the Charee series, while the other two species are lower Charee forms. The Charee group, it may be noted, is the equivalent of the major portion of the Callovian. Of the Indian Trigoniæ perhaps *T. distincta* alone is comparable in the presence of the median sulcus instead of a carina, though this feature is probably of little systematic value.

All the specimens of *T. moorei* examined have had the umbones slightly worn so that observation on the ornamentation of the initial stage is not possible.

Trigonia moorei Lyc. var.

There is one specimen, an incomplete right valve which differs from the normal *T. moorei* as follows:—

1. The ante-carinal portion is relatively wider.
2. The escutcheon (i.e., posterior to the third carina) is slightly more insunken.
3. The angle of divergence of the teeth is greater. (In the accompanying figure ABC = divergence in the holotype of *T. moorei*, ABD = divergence in the present variety).

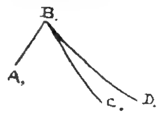


Fig. 3.—*Trigonia moorei* var.

The proportions given in the order noted above are 33 mm. 91, 94, 55.

Genus OSTREA.

Ostrea sp.

The fragments of this genus are not specifically determinable.

AMMONOIDEA.

Genus OTOITES Mascke.

Otoites depressus n. sp.

(Pl. I., figs. 4, 5, 6.)

This species is represented by the impression of one complete individual (holotype) and several fragments. The dimensions are as follows:—

Diameter (at last available point)	35 mm.
Height of last whorl (as percentage of diameter) ..	23
Thickness* of last whorl (as percentage of diameter)	50
Width of umbilicus (as percentage of diameter)	57

The last whorl of the holotype has nineteen ribs which bifurcate or trifurcate at the umbilical bulla. (There are about 43 ribs crossing the venter of the last whorl). The umbilicus is deep, whorl section depressed and venter evenly arched. The

*This measurement is somewhat approximate.

suture line is simple with broad semi-circular saddles and narrow lobes. The tubercle is situated at the junction of L_2 and S_1, and on the inner line of the lappets. Lappets are spoon-shaped, connected by an annular band.

The genus was established by Masske* for *Am. sauzei* d'Orb† (genotype), *Am. contractus* J. Sow‡ and 15 new species. The description of the latter has not appeared up to the present. Two other species, however, *O. delicatus* Buckm.§ and *O. braikenridgii* (J. Sow¶) have since been referred to *Otoites*, while *Sphaeroceras semiornatus* Crick‖ from Western Australia represents another species of the genus. The writer has examined Crick's collection (now in the British Museum) and believes that the *Stephanoceras Australe* Crick** and *Sphaeroceras* (?) *Woodwardi* Crick†† may possibly belong to *Otoites*, though, from the crushed and imperfect nature of the holotypes, they are difficult to determine definitely.

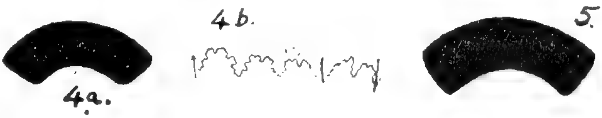


Fig. 4.—*Otoites depressus* n. sp. *a*, Whorl section; *b*, Suture line.
Fig. 5. *Otoites* sp. Whorl section. All natural size.

In suture line *O. semiornatus* is very close to *O. depressus*, but the two forms differ in involution and ribbing. In general shape *O. sauzei* is exceedingly close, but differs in having a smaller umbilicus and more elongated saddles on the septal suture. *O. contractus* is probably even nearer, for like *O. sauzei* it agrees with the present form in number and condition of the ribs, but approaches closer in whorl shape and suture line. *O. braikenridgii* and *O. delicatus* have finer and more numerous ribs, but the whorl section of the latter species is perhaps closest to *O. depressus*. The suture line of these two species is unknown.

Otoites sp.

(Pl. II., fig. 7, a, b, c.)

Another species of *Otoites* is represented by fragments only. It differs from *O. depressus* to which it is very closely allied in having a still more depressed section and finer ribbing. The de-

*E. Maseke; Die Stephanoceras-Verwandten in den Coronatenschichten von Norddeutschland. (Inaug. Dissert. Gottingen, 1907), p. 25.

†d'Orbigny, Paleontologie Francaise, Terrains Jurrassiques, vol. I, pl. 139.

‡J. Sowerby, loc. cit.

§S. S. Buckman, "TypeAmmonites," vol. III., pl. CXLI.

¶See Buckman, loc. cit., vol. II., pl. LXXXI. This is not to be confused with **Am. braikenridgii** d'Orb, the genotype of **Normannites** Mun.-Chal.

‖Crick, On a collection of Jurassic Cephalopoda from Western Australia. (Geol. Mag. Dec. IV., vol. I, 1894), p. 434, pl. XIII., fig. 1.

**Id., p. 391, pl. XII., fig. 4.

††Id., p. 433, pl. XII., fig. 6.

pression of the whorl section reaches a maximum in this species for all known members of the genus. The suture line is very similar to that of *O. depressus.*

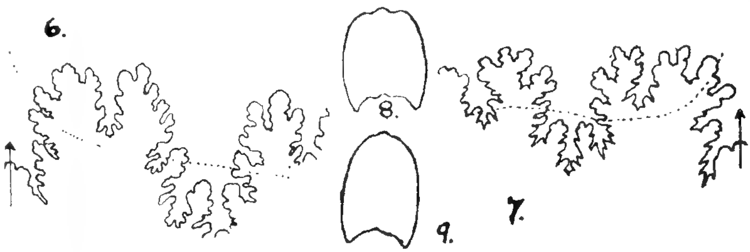
Genus SONNINIA Bayle.

Sonninia spp.

In the collection there are numerous fragments which may be allotted to *Sonninia.* No portion unfortunately shows much more than a third of the whorl; but the whorl section, the carinatisulcate venter, the direction of the radial line and the details of the septal suture agree in all cases with those of Bayle's genus. Several species (at least three) are present and all have features which would place them among the late (degenerate) forms of the genus.

Sonninia makes its first appearance in the *concavum* zone, where it has its maximum development, and extends vertically as far as the *Stemmatoceras* zone, though how much further it goes, if at all, is uncertain.

In the fragments preserved in this collection the ornamentation is never tuberculate and the costæ can only be termed prominent in one or two specimens of about 1 cm. in whorl height. All the larger fragments(they are all internal casts) have sub-



Figs. 6-9.—*Sonninia* sp.;
6, 7. Suture lines of two species.
8, 9.—Whorl sections of two species.
(All natural size.)

costate to smooth whorls. This paucicostate ornamentation, while it is found in certain low forms, e.g., *S. contusa* Buckm., is characteristic of the later species; and its occurrence on all the species of the present collection favours a late horizon in the Sonninian range. The broad-stemmed lobe of the septal suture, which again characterises the present forms, is apparently also a late feature. Further, an advanced stage is shown by the condition of the venter. A comparison of venter and dorsum shows that the carina in each case is hollow and non-septate; and, on one specimen, while the dorsum shows a faint carinatisulcate condition, the venter has become almost smooth.

Until more complete specimens are available comparison with established species cannot be pursued in greater detail.

Dorsetensia clarkei Crick*, which the author believes to be also a *Sonninia*, does not appear to be represented in the collection. Etheridge† has misinterpreted the latter species; for the specimens which he identified under that name are identical with the "*Ammonites Aalensis* var *Moorei* Lycett," of Moore. The species has nothing to do with *Dumortieria moorei* (Lycett), and represents a hitherto unnamed species of *Dorsetensia* proper, for which the name *Dorsetensia etheridgei*‡ is now proposed. The relationships of the species will be discussed in a forthcoming paper.

Gen. INDET.

One large ammonite in the collection cannot be definitely determined generically. It is represented by one complete whorl with a diameter of 1150 mm., and umbilical width of 650 mm. One side of the whorl is badly damaged, so that the thickness is unknown. The whorl is coronate with a single row of very large bosses at the umbilical shoulder, from which ribs trifurcate. The venter is plainly arched and the ribs not prominent. No suture line, unfortunately, can be seen. In ribbing, crassi-tuberculation and lateral dimensions the species would agree very well with *Teloceras*, but there is reason to suppose that the whorl section may not support this. It may perhaps be another and unnamed coronate genus of the Stepheoceratidæ; but until better specimens come to hand this cannot be ascertained. It may be mentioned that the genotype of *Teloceras* is *Ammonites blagdeni* J. Sow. Under the name *Stephanoceras blagdeni* that species was recorded from Western Australia by Neumayr§, but his identification is in error.

BELEMNOIDEA.

Genus BELEMNOPSIS Bayle (em. Stolley).

Belemnopsis spp.

Pl. II., figs. 8-15.

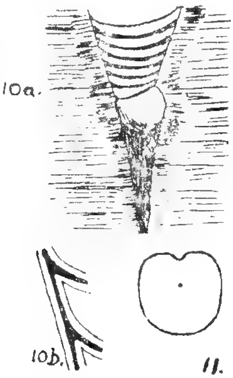
Members of this genus constitute the major portion of the collection. More than one species appears to be present, but only three young individuals have complete guards. The rest of the collection consists of fragments. The guards are cylindrical, though some young forms are subclavate; cross section is circular and the ventral groove is deep narrow and persistent throughout. A short antero-dorsal groove is also present, somewhat prominent in young specimens, but decreasing in intensity with age. The structure of the septa is of the normal type.

*Crick, loc. cit., p. 388, pl. 12, fig. 2.

†Etheridge, Oolitic Fossils from the Greenough River. (Geol. Surv. West. Aust., 1910, Bull. 36), p. 38, pl. VI., fig. 4, IX., fig. 7.

‡Holotype: Etheridge loc. cit. (1910), pl. IX., fig. 7. The dimensions of the specimen figured by Moore are 58, 31, 19, 46.

§Neumayr: Die geographische Verbreitung der Juraformation. (Denk. d. k. Akad. Wiss. Wien. Math.-Nat. Kl. Bd. L., 1885), p. 118, pl. 1, fig. 3.



Figs. 10., 11. *Belemnopsis* sp. *10a,* lateral section of alveolar apex (× 15): *10b,* structure of septa, highly enlarged (about × 80); *11,* transverse section of guard (natural size).

Boehm has separated the group of *Belemnites meyrati* Ooster from *Belemnopsis* under the name *Dicoelites**, the genus being distinguished by its antero-dorsal groove. The relations of the two genera have not been worked out. An examination of the canaliculate belemnite of the Jurassic shows that an antero-dorsal groove is present in forms from most horizons. In some species the groove is prominent, in others it is faint; in others again it is difficult to say whether it is present or not, while in some forms it is definitely absent. No work has ever been done on the zonal changes of the group, and most authors have neglected to record the dorsal groove when it is but faintly shown. It might appear that two lineages are present throughout the major portion of the range of *Belemnopsis.* But the writer believes that the faint dorsal groove is a natural feature of *Belemnopsis* of varying intensity, sometimes disappearing altogether. In certain forms it seems as if the groove may or may not be present in the same species. The present specimens all possess the feature,, though in the specimen referred to *Belemnites canaliculatus* Schloth by Moore† the groove cannot be seen.

Comparison with extra-Australian species is difficult for similar forms occur at many horizons. The Aalenian *B. subblainvillei* (Eud-Desl)‡ is similar, but it is not known whether a dorsal groove is present. The Bajocian *B. blainvillei* (Voltz)§, apparently the

*Boehm: Neues aus dem Indo-Australischen Archipel (Neu. Jahrb. f. Min., etc., Bd. XXII., 1906), p. 389.

†Moore, loc. cit., p. 230, pl. 16, fig. 7. The specimen has been seen by the writer. The apparent absence of the groove may, however, be due to the imperfection of preservation of the specimen.

‡Eudes-Deslongchamps: Le Jura Normand (Paris 1878), p. 60, pl. VII., figs. 5-9.

§Voltz. Observations sur les Belemnites. p. 57, pl. 1, fig. 9.

descendant of the latter species, is also closely comparable. Specimens occurring in the *Garantiana* zone of England, which may belong to the latter species have dorsal grooves of similar intensity to those on the present specimens. The Bathonian *B. bessinus* (d'Orb)* greatly resembles the present forms, but its dorsal features are unrecorded. The Oxfordian *B. tanganensis* (Futt)† from East Africa is again similar but more clavate; while the unfigured fragments from an indefinite horizon in Somaliland recorded by Crick‡ are very like the present fragments in being of a cylindrical form circular in section and apparently with a very similar ventral groove. Two of the species recorded by Boehm from the Dutch East Indies (*B. alfuricus* Boehm§ and *B. galoi* Boehm¶) may be cited for comparison. That collection was referred to the Oxfordian, but both Callovian and Oxfordian ammonites appear to be represented. Most of his specimens from Wai Galo seem to be derived from the bed of a creek (the belemnites, however, being found in situ associated with *Phylloceras*), so that the horizon of the two species quoted is not definite. Of the specimens referred to *B. alfuricus*, those illustrated in the text are most similar to the Australian forms.

It may be mentioned, in passing, that while all species of canaliculate belemnites with anterodorsal grooves cannot be referred to *Dicoelites* the genus may perhaps be retained for the late *meyrati* group.

Age of the Deposit.

The uniform character of the matrix suggests that the specimens are derived from one horizon. The only facts of association to be noted are that a *Trigonia moorei* occurs in the matrix of the holotype of *Otoites depressus*, while in another specimen *Trigonia moorei* and a *Belemnopsis* are associated.

Owing to its limited stratigraphical range the genus *Otoites* is of paramount importance in a consideration of age. According to Mascke it ranges through the three zones of *Emileia, Otoites* and *Stemmatoceras* of the middle Bajocian. Should the undetermined genus prove to be *Teloceras*, as is indeed possible, greater precision in determining the age of the association is possible, for that genus is recorded from the *Stemmatoceras* to the *Garantiana* zone (*fide* Mascke). Degenerate Sonniniæ similar to the fragments described above occur in the zones of the Middle Bajocian roughly equiva-

*See Phillips: Monograph British Belemnitidae (Pal. Soc. 1868), p. 106, pl. XXVI., fig. 6, 3.

†Futterer; Beitrage zur Kenntniss der Jura in Ost-Afrika. (Zeit. d. deut. geol. Gessell, vol. XLVI. 1894), p. 30, pl. V., fig. 2, 3.

‡Crick, Notes on some fragments of Belemnites from Somaliland. (Geol. Mag. Dec. IV., vol. III., 1896), p. 296.

§Boehm, Beitrage zur Geologie von Niederlandisch-Indien (Palaeontographica Supp. IV. Lief. 2. Abt. I., Ab. 2, 1907), p. 57, pl. VIII., figs. 4-11.

¶Ib. (Ab. 3.), p. 66, pl. X., figs. 1, 2.

lent to those of the range of *Otoites*, so that confirmatory evidence for a Middle Bajocian age is thereby afforded.

The *Pseudomonotis*, *Oxytoma* and "*Cidaris*," as indicated above give little definite evidence regarding the age; while the *Trigonia*, *Belemnopsis* and *Berenicea* have been shown each to have affinity with forms ranging from at least as low as the Aalenian to the Oxfordian. These members of the fauna, then, while giving no precise evidence themselves, in no wise invalidate the evidence given by the Ammonites. The fossils would thus indicate a middle Bajocian age; and it appears that they may even be derived from a single zone to be correlated with one of the three zones represented in Europe by the range of *Otoites*.

Further remarks on the age of the Jurassic beds of Western Australia as a whole are deferred until, in a later paper, the writer has an opportunity of revising the collection described by Moore and Crick.

The writer would wish to record his indebtedness to Sir Edgeworth David and Mr. W. S. Dun for allowing him to examine the collection; to the authorities of the British (Natural History), and Bath Museums for permission to consult type collections, and to Dr. H. Schmidt, of Gottingen for the loan of a copy of Mascke's Vorbericht.

EXPLANATION OF PLATES.

(All figures natural size except 1b and 2c.)

I.

1. *Cidaris* sp. *a*, Imperfect spine; *b*, ornamentation of same (× 6).
2. ?*Pseudomonotis echinata* (J. Sow). *2a*, exterior; *2b*, interior, of shell; *2c*, ornamentation (× 4). Owing to the fact that in *2a* all the ribs are drawn of equal intensity, the appearance of the figure is a trifle misleading. The ornamentation of the central portion is, however, enlarged in *2c*.
3. *Oxytoma decemcostata* n. sp. Left valve.

4-6. *Otoites depressus* n. sp. *4*, artificial impression taken from the holotype (an external mould); *5a*, ventral view of aperture of a fragment (internal cast) showing lappets and connecting band; *5b*, the same specimen in lateral view; *6a*, another speci-

men (internal cast) consisting of portion of body chamber, ventral view; *6b*, the same specimen in lateral view.

II.

7. *Otoites* sp. *7a*, sectional view of portion (body chamber) of an internal cast; *7b*, the same specimen in lateral view; *7c*, the same specimen in ventral view.

8-15. *Belemnopsis* spp. *8-10*, *13-15* ventral view; *11*, dorsal view; *12*. sectional (lateral) view; *9,10*, two young individuals, possibly of different species.; *11*, a young specimen with pronounced antero-dorsal groove; *13*, the largest specimen; *14*, *15*, two different types of apex.

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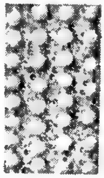
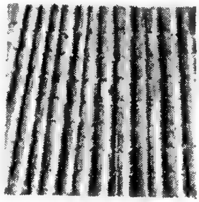
1a

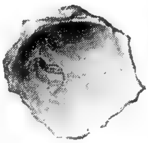


1b

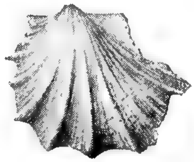


2c

2a

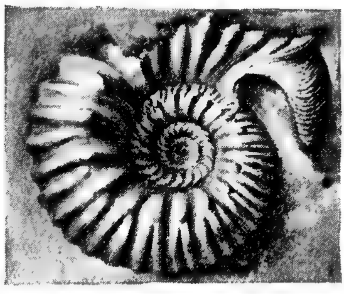


2b

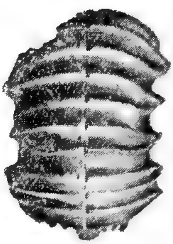


3

5a

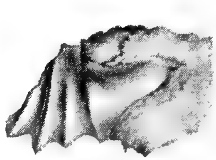


4



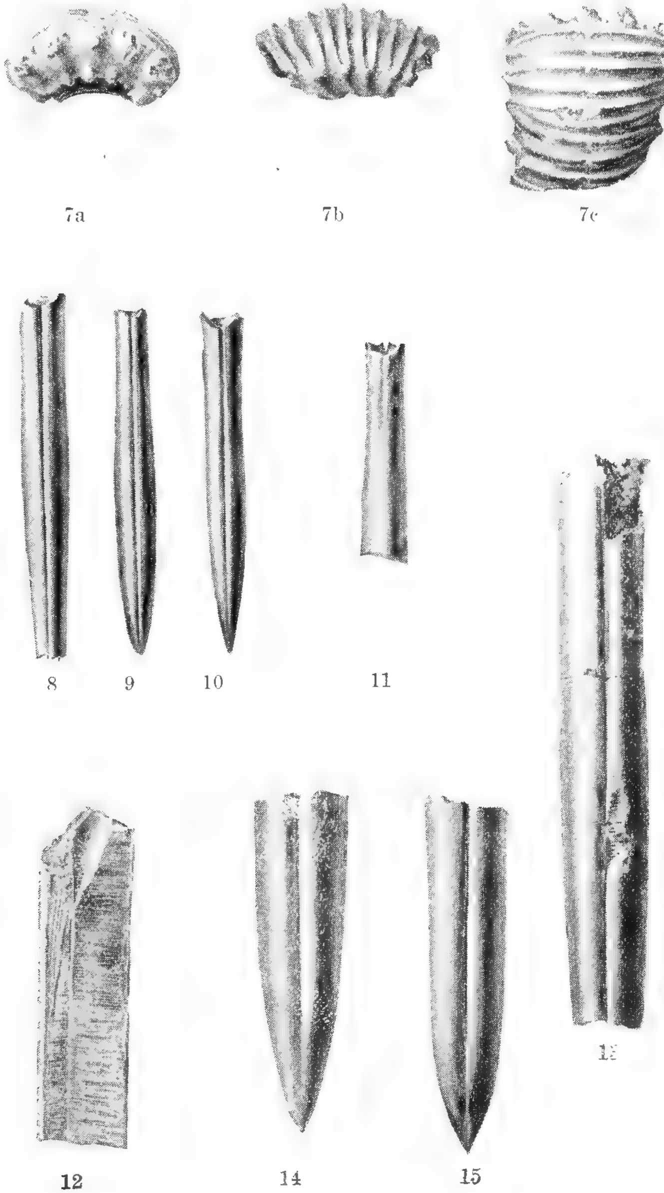
5b

6b



6a

E. F. Talbot, del.



E. T. Talbot, del.

The occurrence of the criniod Uintacrinus in Australia by Thomas H. Withers, F.G.S., *Communicated by* L. Glauert.

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(*Read* October 14, 1924. *Published* November 20, 1924.)

Much credit is due to Mr. Glauert, of the Western Australian Museum, Perth, for his continued interest in the fossils of the Gingin "chalk," for it has resulted in the finding of the remains of the unstalked crinoid *Uintacrinus*. Soon after the publication of my paper on the only known Australian Cretaceous Cirripede *Calantica (Scillaelepas) gingninensis* (R. Etheridge, jnr.), (1924, Journ. Roy. Soc. W. Austr., vol. ix., pt. ii, p. 64, pl. i), Mr. Glauert sent me, at my request, some "chalk" from Gingin so that it could be washed for additional valves of that Cirripede. The results were not particularly successful so far as Cirripedes were concerned, but two Crinoid plates were found which, although not at all well preserved, seemed to me to represent the cup-plates of *Uintacrinus*. This, combined with the fact that Etheridge (1913, Bull. 55, Geol. Surv. W. Austr., p. 11) mentioned "disarticulated Crinoid plates, and arm-ossicles" among the Echinoderms recorded, induced me to send to Mr Glauert some drawings of plates of *Uintacrinus*, with the request to send me any similar plates that he had. In response he not only sent me, through the kind offices of Mr. C. L. Egremont Orton, of Moora, W. Australia, some plates of that Crinoid, but he also took the trouble to send some additional "chalk" to wash. This last proved very interesting, for from it were obtained some further cup-plates, which conclusively proved that they were *Uintacrinus* plates, but as in Mr. Glauert's material, furnished also examples of arm-ossicles.

Shortly afterwards Mr. G. Spencer Compton asked me to examine a suite of fossils which he had collected from the Gingin deposit, and had brought to England with him, and this included some further undoubted cup-plates of *Uintacrinus*.

Uintacrinus is not only one of the most easily recognisable of the fossils of the English Chalk, but it is one of the most useful. Its importance lies in the fact that it is confined to a definite and restricted horizon, the *Uintacrinus*-band, which forms the lower part of the *Marsupites* zone of the Senonian. Except in rare instances, *Uintacrinus* is represented only by the disconnected cup-plates and arm-ossicles (brachials), and since these occur quite commonly and often outnumber the associated fossils, they are readily found on weathered surfaces or by breaking up blocks of chalk.

Uintacrinus (*U. socialis* Grinnell) was first found* in the

* 1871. Marsh, O. C. "On the Geology of the Eastern Uintah Mountains: Amer. Journ. Sci., ser. 3, vol. i, p. 195.

Uintah Mountains, in north eastern Utah, but was described †‡on better preserved material from Trigo Co., Kansas. Almost immediately afterwards* *Uintacrinus* (*U. westphalicus* Schlueter) was found in the Senonian of Recklinghausen, Westphalia. Its occurrence in the English Chalk was recognised by Dr. F. A. Bather from material submitted by Dr. A. W. Rowe and C. D. Sherborn (see Bather, F. A., 1896, "The Search for *Uintacrinus* in England and Westphalia," Geol. Mag., dec. iv., vol. iii. pp. 443-445). It occurs quite commonly in the Marlstone of Westphalia, and since its recognition by Dr. Bather it has been proved by Rowe and Sherborn, and other chalk workers, to be one of the most useful guide fossils of the English chalk. A more detailed study of the morphology of the Kansas form has been made by Dr. Bather (vol. 1895, Proc. Zool. Soc., London, pp. 974-1004, pls. liv.-lvi., April, 1896), and a good figure drawn under his direction, has been given of some associated plates from Margate (here reproduced, pl. iii, fig. i) in Rowe and Sherborn (1900, "The Zones of the White Chalk of the English Coast, Pt. I., Kent and Sussex," Proc. Geol. Assoc. London, vol. xvi., pt 6, p. 298). Its wide distribution in America is evidenced by its being found in Utah and Kansas at localities over five hundred miles apart. Upwards of twelve hundred specimens of *U. socialis* from the Niobrara Chalk of Kansas were collected by F. Springer (1901, "*Uintacrinus*: its Structure and Relations": Mem. Mus. Comp. Zool. Harvard, vol. xxv., No. 1), in which more or less of the calyx is visible, and a single slab measuring 8ft. by 4ft. contains about one hundred and twenty-five specimens, many of them with long arms and finely preserved.

That *Uintacrinus* should now be found in the deposit at Gingin, W. Australia, is therefore of very great interest, and lends point to the view expressed by Dr. Bather (1896, Geol. Mag., p. 444) when noting its occurrence in the *Marsupites* zone of Westphalia and England, that it occurs "probably at the same horizon in a good many other countries."

The Gingin specimens consist of nine detached cup-plates and 13 arm ossicles (brachials), and although R. Etheridge, jnr. (1913), must have had other specimens, there is no evidence as yet that the plates occur commonly. No plates of the unstalked Crinoid *Marsupites* have been found with them, but it may be that there is not a sufficient thickness of the deposit to allow of its occurrence in the beds above, although in the English chalk it is occasionally found associated with the plates of *Uintacrinus*. There is also no evidence of the occurrence of the stalked Crinoid *Bourgueticrinus*. The cup plates of *Uintacrinus* have their outer

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† 1876. Grinnell, G. B. "On a new Crinoid from the Cretaceous Formation of the West": Amer. Journ. Sc., ser 3, vol. xii, pp. 81-83.

‡1876. Meek, F. B. "Note on the new genus *Uintacrinus* Grinnell": Bull. U.S. Geol. & Geog. Sur., vol. ii. pp. 375-378.

* 1878. C. Schlueter, "Ueber einige astylide Crinoiden" Zeitschr. deutsch, geol. Ges., Bd. xxx, pp 28-66, pls. i-iv. "iii. **Uintacrinus Westphalicus**, ein ungestielter tesselater Crinoid aus dem Senon Norddeutschlands," pp. 55 63, pl. iv, figs. 1-5.

surface smooth, they are flattish and not very thick, and usually of a pentagonal or tetragonal outline. On their inner surface they are usually [illegible] presence of wide V-shaped grooves (pl. iii, figs. 2, 3, 4), radiating from the centre to the sides, not [illegible] identification. These peculiar [illegible] the passage of muscles and nerves connecting the [illegible] plates. The arm-ossicles (brachials) are often characterised by a diagonal fulcral ridge (pl. iii, figs. 7, 8), but in others there are a number of weak ridges radiating from the periphery to the axial canal (pl. iii, figs. 9, 10).

Some uncertainty still [illegible] whether the Westphalian form (*U. westphalicus*) and the English form (*U. sp.*) of *Uintacrinus* represent a single species, and also whether this is identical with the Kansas form (*U. socialis*). F. Springer (1901, p. 87) is of the opinion that the American and European forms represent a single widely distributed species, which, of course, must bear the name *U. socialis* Grinnell. The Gingin material is insufficient to throw any light on this subject, but the resemblance of the radial plate (pl. iii, figs. 4a, 4b), from Gingin, to a radial plate (pl. iii, figs. 3a, b) from [illegible]. In any case the discovery of these Gingin pieces is an important addition to the geographical distribution of *Uintacrinus*.

Age of the Gingin Deposit.

The early history of the Gingin deposit is given in a paper by L. Glauert (1910, Geol. Surv. W. Austr., Bull. No. 36, pp. 115-127; see also A. Gibb Maitland and A. Montgomery, 1912, Bull. No. 50, p. 22), where he gives a preliminary account of some of the fossils. In this paper full references are given to previous writers. Mr. Glauert insists on the Cretaceous age of the beds, although R. Etheridge, jnr. (see A. Gibb Maitland, 1907, Geol. Surv., W. Austr., Bull. No. [illegible], p. [illegible]) tentatively suggested an Upper Tertiary age for the deposit. Later R. Etheridge, jnr. (1913, Geol. Surv. W. Austr., Bull. No. [illegible], iv., Palaeont. Contrib. to The Geology of Western Australia, pp. [illegible], pls. I.-IV.), described the fossils of the Gingin deposit, and suggested the beds were of Upper Cretaceous age. F. Chapman (1917, Geol. Surv. W. Austr., Bull. No. 72, Palaeont. Contrib. to The Geol. W. Austr., "Monogr of the Foraminifera and Ostracoda of the Gingin chalk"), basing his opinion on the Foraminifera, states (p. 15): "On the whole, however, the fauna is decidedly of Albian *cum* Cenomanian relationship, and not of Aptian or Lower Cretaceous." Of the Ostracoda he states (p. 52): "The balance of evidence from the Ostracoda is therefore clearly in favour of a correlation with the lower part of the Upper Cretaceous, that is Albian."

L. Glauert (192[illegible], Journ. Roy. Soc., W. Austr., vol. ix., pt. 1., p. 48) subsequently described from these beds an Echinoid, *Cidaris comptoni*, which represents the first known Australian Cretaceous species of Echinoidea, but he did not discuss further the age of the Gingin deposit.

In my paper on the Cirripede *Calantica* (*Scillaelepas*) *gin-*

ginensis (R. Etheridge, jnr.), 1924, Journ. Roy. Soc. W. Austr., vol. ix., pt. ii., p. 66) the horizon was not only given as Upper Cretaceous, but I ventured to put "(?Upper Senonian.)" This opinion was not so much based on the occurrence of the Cirripede, but the associated fossils seemed to me to suggest an Upper as opposed to a Lower Senonian age for the beds.

The discovery of such a fossil as *Uintacrinus*, marking as it does in Europe a definite horizon in the Senonian, namely the *Marsupites* zone, which forms the upper part of the Santonian or middle division of the Senonian,* seems to place the Santonian age of the Gingin deposit beyond doubt. Whether it is exactly equivalent to the *Marsupites* zone of the European Cretaceous is a question that cannot be settled until the associated fossils have been studied in more detail. In such a distant geographical area, there is a possibility that *Uintacrinus* might occur a little lower or a little higher in the sequence, although still within the limits of the Santonian or middle division of the Senonian.

In conclusion I wish to express my thanks to Mr. L. Glauert for the very great trouble he has taken to supply me with material. I have also to thank Mr. G. Spencer Compton for kindly adding to this, and with his name should be associated that of Mr. C. O. A. Thomas, who has collected so intensively in the deposit at Gingin.

EXPLANATION OF PLATE III.

Uintacrinus socialis Grinnell.

1. Nearly complete specimen from the Niobrara Chalk of Kansas, U.S.A. Natural size. (Reproduced from F. Springer, 1901, pl. v., fig. 2)

Uintacrinus sp.

2. Several plates in the natural position; natural size. C, centrale; B, basals; R, radials; IBr_1, first primibrach; IAx, primaxil second primibrach; $IIBr_1$, first secundibrach; iBr, interbrachials. The detached plate is a radial, from Westgate, viewed on the inner surface. Coll. A. W. Rowe. Gilbert C. Chubb, del; F. A Bather, dir. (after F. A. Bather in Rowe).
3. Cup-plate (radial) from Keston, Kent: a, outer view; b, inner view, × 2. Brit. Mus., E. 24935.

Uintacrinus sp.

Middle Senonian (Santonian): Gingin, Australia.

4. Cup-plate (radial): a, outer view; b, inner view. × 4. Brit. Mus., E., 24939.
5. Cup-plate. × 2. G. Spencer Compton coll., Brit. Mus., E. 24936,
6. Cup-plate. × 4. G. Spencer Compton coll., Brit. Mus., E. 24937.
7. Articular or joint surface of a normal brachial. × 4. Brit. Mus., E. 24940.
8. Same. × 4. W. Austr. Mus.
9. Joint surface of a syzygial brachial. × 4. Brit. Mus., E. 24941.
10. Same. × 4. W. Austr. Mus.

*In Lang, W. D., 1921, Brit. Mus. Cat. Cretac. Bryozoa, Vol. 3, pl. XVIII.

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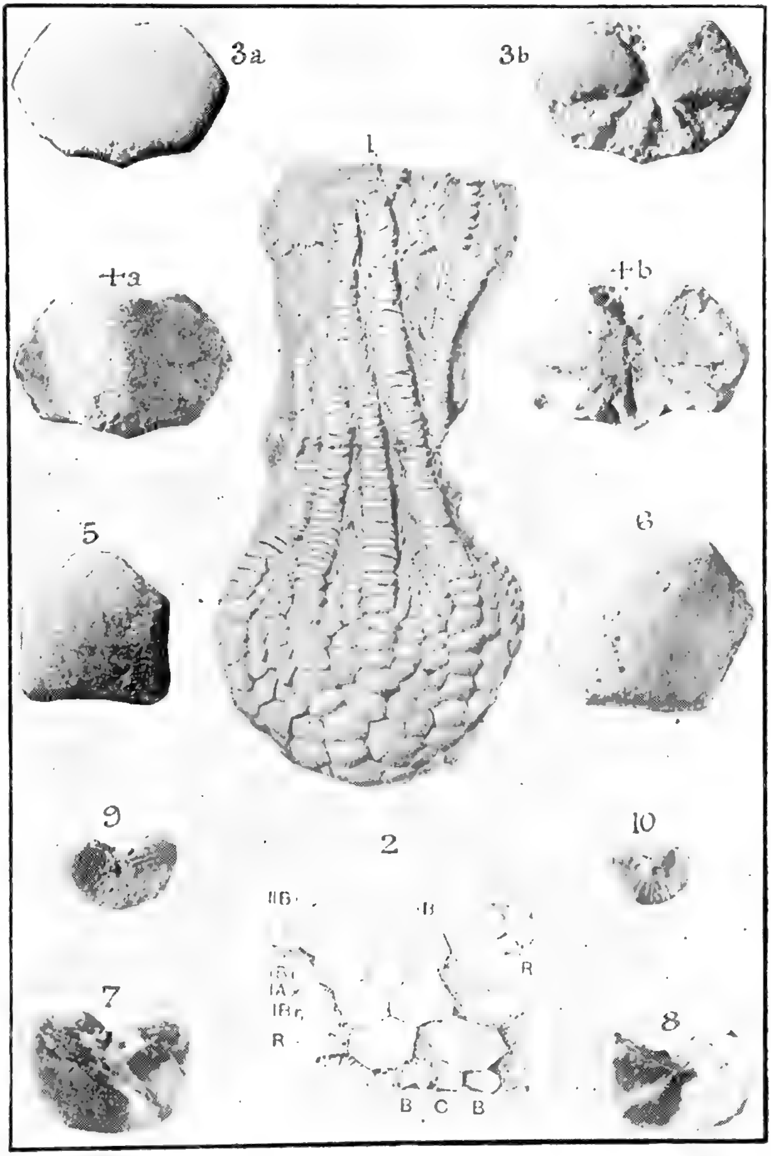

H. G. Herring, photo.

Uintacrinus.

A New Species of Darwinia by C. A. Gardner.

(*Read* November 11, 1924.—*Published* November 20, 1924.)

Darwinia polycephala, n. sp.

Parvus diffususque frutex, ramis numerosis, diffusis, ramis foliorum lapsorum signa ferentibus. Foliis parvis in lateralibus ramis, congestis, imbricatis, oblongo-clavatis, subteretibus aliquantulum carnosis, supra leviter planis, obtusis sessilibus, apici valde minute ciliatis.

Floribus sessilibus quinque aut septem simul efformantibus exiguis capitibus terminalibus. Bracteis ovato oblongis, obtusis, exigue ciliolatis inter flores copiosis non tamen involucrum definitum efficientibus, luteo-pallidis, membranaceis, modice longioribus foliis quibus externe in lineamentis adsimilantur, tenuioribus tamen atque latioribus. Tubo-calycis turbinato-cylindrico, quinque costis efformato, costis conspicuis; lobulis deltaico-orbicularibus, obtusis, ciliatis. Petalis purpureis, ovatis, obtusis, concavis, parum longioribus tubo calycis elatis. Staminibus staminodiisque equalis longitudinis, parvis, staminodiis insuper linearibus-clavatis. Stylo duplo circiter longiore petalis, basi incrassato, ceterum tenui; stigmate capitato, piloso-glandulari, stylo sub stigmate potius longis pilis barbato.

Frutic ca. 20cm. altus. Folia 2- 2.3mm. long., .8mm. lata. Bracteis ca. 3mm. long. Flores circa 4.5 mm. long., calycis tubus 2mm. long., lobi ca. .8mm. long., petala 2.5mm. long.

HABITAT prope GRASSPATCH, in arenosis in densitate arbuscularum, inter arbuscula et sub umbra illarum, flor. mense Majo. Numerus typi est 2215 in Herbarium apud "Forests Department."

Haec nova species videtur esse vicinius speciei D. pauciflora, Benth., ab hac principaliter discrepans in sessilibus floribus, etiam in longioribus calycis lobis, necnon angustiori calyci, integris petalis, stylo longiori, &c.

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A NOTE ON THE ACTINIC VALUE OF LIGHT by A. KNAPP.

(*Read*, November 11, 1924. *Published*, December 12, 1924.)

The practice of photography consists of a series of chemical processes most of which may now be carried out with scientific accuracy. The most difficult and certainly the most important problem with which the outdoor photographer is confronted, is that of estimating the correct exposure for any given subject, and it is unfortunate that so far no infallible and practical method has been evolved whereby scientific exactitude in this matter may be achieved. The exposure of a plate decides once and for all the possibilities of the resultant negative. If the exposure has been insufficient, the negative will show a lack of detail in the shadows of the objects photographed; a lack of detail which no subsequent process can supply and for which the only remedy is the exposing of another plate.

Every photographic textbook devotes many pages to this matter and emphasises the importance of sufficient exposure as being the basis of all good photography, a view which would surely be supported by experienced photographers. That the problem of sufficient exposure is not easy of solution will be obvious when it is remembered that a photograph of the luminous filament of an electric lamp may be secured in a fraction of a second with the cheapest camera now on the market, but to secure a photographic record of the fine scratches on a blackboard illuminated by the same electric lamp and with the same camera might require several hours.

Correct exposure should be determined by a measurement not only of the quantity of light admitted to the plate, but also, which is far more important, of the quality of that light. The quantity of light might with experience be estimated by the appearance of the image on the ground glass focussing screen, or by an instrument designed to measure the visual intensity of the light falling on the densest shadows of the objects to be photographed, such as, for example, the "Heyde Photometer."

Unfortunately there is no fixed ratio or connection between the visual brightness of light as appreciated by the eye and the chemical or actinic force of light to which the photographic emulsion is sensitive. The eye is most sensitive to the yellow portion of the spectrum, while all ordinary photographic plates and films are most sensitive to the blue, violet, and ultra violet

rays, quite blind to red and some greens, and only slightly sensitive to orange and yellow. This is the explanation of the hopelessly incorrect rendition of many colour schemes in monochrome. For instance, a rich blue dress with a bright yellow sash would be photographically represented as a white dress with a black sash.

The problem of correct exposure requires for its solution a measurement not only of the intensity, but also of the actinic value of the light which is falling on the subject. This fact has long been recognised, and many simple instruments have been designed for the purpose of making such measurements.

The principle on which these actinometers are designed is as follows:

A piece of sensitised paper is exposed to the light falling on the subject until it is darkened to the same tone as a standard tint with which it is to be compared. The time in seconds which elapses during this process is counted and the figure thus obtained constitutes a measurement of the actinic force of the light, and a base from which to calculate or estimate the correct exposure.

Another plan which of course is based on observations of the actinic value of light is that of taking into consideration the month, hour, kind of weather, speed of plate, lens aperture and general nature of the subject, and consulting tables or a slide rule compiled from the experience of many workers. The Burroughs and Wellcomes calculator is an excellent example of this system of exposure meter.

All these systems or methods of calculating exposures regard bright sunlight during the middle hours of the day as the standard of actinic value, and all are equally unanimous in recommending that for other conditions of light such as diffused light when the sun is behind clouds and no well defined shadows are cast, the exposure should be doubled, while if the sky is overcast and no sun is visible, the exposure suitable for bright sunlight should be multiplied by three or four. It is generally accepted that the actinic value of the light of the sun is decreased when passing through clouds.

About twelve months ago I had reason to suspect that the actinic force of bright sunlight varied very greatly in different parts of Australia, notably between Melbourne and Perth. I therefore decided to make tests by means of an actinometer of the actinic force of light in Perth. My observations were made under all varieties of lighting conditions extending over a period of about eight months.

Instead of finding that our bright sunlight recorded the highest actinic value, I found that the value increased from two to four times when clouds were present in the sky. Even heavy rain had the effect of increasing instead of decreasing the force of the light.

Through the kindness of Mr. Johnson, the director of the Magnetic Observatory at Watheroo, and Mr. Tarlton Phillipps of Balingup, I have been able to obtain measurements from these two localities, which are quite in accordance with accepted theories but diametrically opposed to the conditions in Perth. The following are typical measurements, the numbers being the measures of the actinic values. All tests were made between 10 a.m. and 3 p.m.

Place.	Bright Sunlight.	Diffused Light.	No Sun Visible.
Perth	45	12 to 20	15 to 30
Watheroo	10	12	22
Balingup	10	12	20

All these tests were made while interposing my body between the exposure meter and the sun. Only a few tests were made in Watheroo and Balingup while I had made about forty in Perth.

From the above it would appear that the value of diffused light varies but little in these localities and that the actinic value of bright sunlight in Perth is less than one quarter of that of the other two localities. This is supported by the fact that very good results may be obtained in Melbourne with cheap snapshotting film-cameras which, when used for the same class of subject in Perth, gives almost useless results.

It would appear that the unusual conditions to which I have referred might perhaps have a wider application than the mere estimation of photographic exposures, and I have therefore brought the matter before the notice of members in the hope that some effort may be made to map out the area or areas where abnormal lighting conditions exist, and perhaps establish the cause or causes for such variations in the actinic value of the sunlight in this State.

Printed for the Royal Society of Western Australia by R. S. Sampson, 971-973 Hay Street, Perth.

Construction and efficiency of crystal receiving sets in wireless telephony by D. W. Everson.

Communicated by R. D. Thompson.

(*Read* November 11, 1924. *Published* January 15, 1925.)

For headphone reception within twenty miles of a broadcasting station the crystal detector has many advantages, being easy to operate, pure in tone, and cheap to instal and maintain. During the past ten years very little scientific work has been done with crystals, as valves received most of the attention, but there are now signs of renewed interest in crystal-reception. Wonderful improvements are being made in the production of synthetic crystals of great sensitivity, and there is no doubt that when we understand the principle of contact rectification better, crystal sets will afford a very convenient means for the reception of broadcast telephony.

A complete receiving set comprises aerial, earth connection, detector, and some means of tuning the aerial and telephone receivers.

Aerial.—Since the whole of the energy available for conversion into sound has to be drawn from the ether by means of the aerial, and there is no means of adding to this energy by any local source, it is essential that the aerial should be as high as possible and well insulated. In a series of experiments carried out on crystal receivers, 100ft. of 16G. wire, 20ft. high, were used as an aerial, it being considered that these dimensions were the most suitable for suburban residents, although an increase in height, length and area of cross-section of wire would be an improvement. The lead-in wire should preferably be insulated, and should enter the building through a tube insulator, thus reducing the losses to a minimum.

Earth Connection.—A good contact to earth is necessary and can usually be obtained by soldering an insulated wire to a water pipe, or in the absence of a water supply, by burying a metal plate edgewise in the ground. Best results are obtained when the ground is damp.

Detectors.—These are procurable in a variety of makes, and the only requirement is that the contact at the "ball fitting" should be sound and lend itself to easy adjustment.

Aerial Tuning.—Every aerial has its own or fundamental wavelength, which varies in different aerials according to size and local

conditions. When it is desired to receive signals or music from a given station, it is necessary to reduce or increase the natural wave-length of the aerial to that of the station. This can be accomplished in a number of ways, but as we are considering sets suitable for our local station, 6 W.F., we shall confine ourselves to methods of increasing the natural wave-length to 1250 metres. Taking 200 metres as a fair average for the natural wave-length of an aerial, we see that it will be necessary to load up to the extent of about 1050 metres. The question at once arises as to the best way of doing this. There are at least five possible ways, viz.—by adding inductance (i) tuned by a series condenser, (ii.) tuned by a parallel condenser, (iii) variometer tuned, (iv.), tuned by sliding contact, (v.) tuned by tapping. From a number of experiments carried out in which headphones were used for detecting the variations of intensity, no decided difference could be found in the efficiency of any particular set. It is, however, well known that as a gauge of comparatively small differences of intensity the ear is very defective. With sounds of moderate intensity 5 per cent. is probably the best accuracy of comparison that can be obtained. If the time interval between the sounds is ten or fifteen seconds, or even more, it is doubtful whether a 50 per cent. change can be detected with any certainty. There is thus very little to be gained by unnecessarily striving after the utmost efficiency, although of course a reasonable efficiency is essential. We may summarise the results obtained by the use of the different circuits as follows:—

Series Condenser Tuning.—While this arrangement of condenser tuning is very popular, it is not found satisfactory for crystal reception. The condenser losses are high, and gradually increase as the scale readings decrease. This is to be expected, as there is almost a break in the aerial lead when the condenser is at zero.

Parallel Condenser.—This is an improvement on the previous method, as the condenser losses are more nearly constant.

Inductance Tuning. By far the best results are obtained when inductance only is used for loading. This may be accomplished by three different methods, but there is so little difference between the results obtained that mechanical construction, compactness, and general lay out decide which is the best method to adopt. The sliding contact system is not considered mechanically sound, there being a tendency to displace the end turns, a defect which will become more pronounced during the summer months. The tapped coil system is very good and easy to construct, but the method of variometer tuning is undoubtedly the best. Variometers are capable of a high degree of efficiency, and reduce the dead-end effect to a minimum. They are mechanically strong, and if constructed to the details given below, they will be found to give every satisfaction.

It is found that in every instance single layer coils are superior to the "plug in" type. As to the relative merits of coupled and

single circuits, I am in favour of the single circuit for local broadcasting. It is much simpler to operate, costs 50 per cent. less, and is more efficient on a wave length of 1250 metres, since in a coupled circuit the coupling, to be of any use, must be loose. The chief advantage of the coupled circuit lies in its remarkable selectivity. This, however, will be of little value in the reception of 6 W.F., as the only interference comes from the Applecross Station, which is at present undergoing alterations, and will eventually use continuous wave signals of a wave length much shorter than that of the broadcasting station. Even these signals will be curtailed to an absolute minimum during concert hours. As an example of the relative efficiency of a single circuit on two different wave lengths, we may take the case of 350 metre transmissions. If the wave-length of the aerial is equal to 150 metres, it will be necessary to add loading equal to 200 metres. Now the crystal is placed across the loading coil and therefore is across 200/350 × 100 = 57 per cent. of the total energy in the circuit. In the case of 1250 metre transmission on the same aerial the loading would have to be equal to 1100 metres, and therefore the crystal and telephones are across 1100/1250 × 100 = 88 per cent. of the total energy. From the above it can be seen that in the case of 350 metre transmission (British) the coupled circuit is an advantage, while the local transmissions would require a coupling in which the losses were less than 12 per cent. to attain the same standard as the single circuits. But it is practically impossible to reduce the percentage losses to this small value.

Telephones. It is most essential that high resistance telephones be used. The reason is not because they have high resistance, but because they are wound with a very large number of turns, and therefore owing to the high external resistance of the circuit, the magneto-motive force is increased to a greater extent than it is decreased by the higher resistance of the telephones. For example, if a coil of 10 turns and resistance 1 ohm is placed in a circuit of total resistance 100 ohms, then 1 volt will cause a current of 0.01 amps. The magneto-motive force will therefore be 0.01 × 10 turns =0.1. On the other hand, if the coil is wound with wire of one-tenth the area of cross section the resistance will be 10 times greater; also there will be 10 times as many turns. In this case the resistance of the coil would be 10 × 10 × 1 = 100 ohms, which added to the resistance of the circuit (99 ohms) gives a total resistance of 199. Then 1 volt will cause a current of 0.005 amps. The magneto-motive force will therefore be .005 × 100 = 0.5. In the example given the increase in force is about 5 times. Now, if we examine the circuit diagram of a receiver we shall see that the telephones come in series with the crystal, which has a resistance of about 10,000 ohms, so the telephone resistance can be increased considerably without affecting the circuit.

The nature of the crystal used as a detector, and the amount of pressure placed on the contact, are vitally important in a set.

Ordinary galena gives very good results, but sensitive spots are hard to find. Most of the synthetic crystals now manufactured, such as Q.S.A., are very good. The condenser across the telephones is not necessary, there usually being sufficient self-capacity in the telephone windings, but it may be an improvement. Sets tuned by variometer or tapped inductance (for both of which circuits, I append full constructional details) undoubtedly yield the best results.

Constructional Details.- For the variometer sets the following components will be required:- Ebonite 7" x 9½", crystal detector and crystal, knob and dial, switch arm, 4 brass screw 1" x ⅛" whitworth and nuts, 2 brass screws ¾" x 6 cask head variometer rotor and shaft assembly, 4oz. 24 G. enamel wire, 1 pair 4000 ohm telephones, 7" cardboard tube 3¼" inside diameter. The total cost will be about £3, with 10/- extra for an aerial equipment (without mast).

For the tapped coil the following is the list of components:—Ebonite 7" x 9½", crystal detector, 2 switch arms, 22 contact studs, 4 limit stops, 4 terminals and nuts, 4 brass screws 1" x 7 cask head, 7" cardboard, 3½" diameter, headphones, 4oz., enamelled wire 24 G. The total cost for this circuit is about £3, with an additional 10/- for aerial equipment without masts.

Working Details. Variometer.—First wind the two halves of the rotor with the enamelled wire starting from the outside and working to the centre. Then clean and twist the centre pair together and solder. To the outside pair solder flexible pigtails. Care must be taken that the direction of the windings of the two halves is the same. Next commence winding the tube about ¼ inch from one end, place on 30 turns, then make a space of ½ inch and continue winding, taking off taps at turns Nos. 60, 100, 145, 200. See Fig. 1.

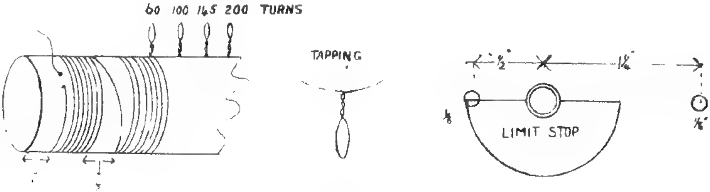

Fig. 1.

Two ¼ inch holes must now be drilled in the tube in the space between the windings, great care being taken to see they are diametrically opposite and at right angles to the axis of the tube.

Then drill ⅛" hole ½" from the centre of one of the ¼" holes and another 1¼ inches away, but in the opposite direction, and through these place a ⅛" whitworth screw from inside the tube and fasten with a nut. Proceed to assemble by pressing the brass bushes into the ¼" holes from the inside, place the rotor in position and fix by passing the spindles through the bushes and screw-

ing into the rotor. The hollow spindle must be placed in the bush nearest to the two screws. After securing with lock nuts, the limit stop is placed on the hollow spindle and the pigtails threaded through, one being secured to the end turn on the tube and the other to the remaining screw which is eventually connected to the aerial terminal.

The panel is next drilled and engraved, after which the various components are mounted and wired up as shown in Fig 2. The coil and variometer can be secured to the panel by two screws at the points marked C and B.

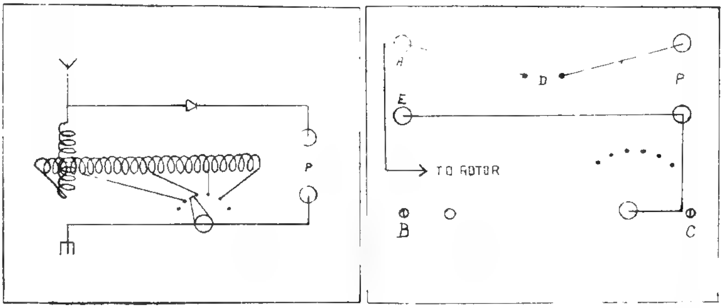

Fig. 2.—Variometer Set A. aerial; P, telephones; E, earth; D, detector. B, C, fixing screws.

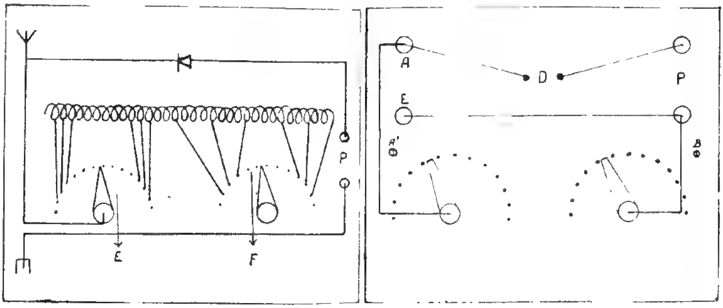

Fig. 3.—Tapped Coil Set. A, aerial; P, telephones; E (in right hand figure), earth; D, detector, A,' B, fixing screws; E (in left hand figure), 11-2 turn taps; F, 11-22 turn taps.

The Tapped Coil.—Wind a 7" tube with 264 turns of 24 G enamel wire, making tapping points every 2 turns for the first 11 taps, and then every 22 turns for the next 11 taps. Connect the 11 2-turn taps to the studs of one switch arm, and the 11 22-turn taps to the studs of the other switch arm, and wire up as shown in Fig. 3.

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Mollusca from the sub-recent shell-beds of the lower Swan River,

by **J. L. Reath.**

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CONTENTS.

INTRODUCTION.

Physiographical and biological investigations in the Eastern States of Australia* have shown that climatic changes have occurred in very late geological times.

In this paper it is proposed to adduce evidence that in almost recent times, the sea washing the south-western shores of Australia was considerably warmer than it is now. At the same time it must be clearly understood that a great deal of material evidence along the lines followed by the writer has yet to be collected and analysed, and it is probable that further work may weaken the case for a recent cooling in ocean temperatures.

Papers read before this society have drawn attention to evidence, in the form of raised beaches, river terraces, etc., of recent uplift to the extent of twenty or thirty feet in the country bordering on the lower Swan and Helena Rivers.†

Aurousseau and Budge mention that the climate before the movements described was warmer than it is now, indications of this fact being obtained from "the older Perth Shell Banks, and the younger Rottnest Shell Banks." The evidence for this statement was that a number of molluscan species, collected by Dr. Simpson and identified by Mr. C. Hedley, have not, so far, been

*Howchin, W.: The recent extension of certain marine animals on the southern coast of Australia, together with other facts that are suggestive of a change in climate. Rep. 16th Meeting, Austr. Ass. Adv. Sci., Wellington, 1923, p. 94.

†Somerville, J. L. Evidences of uplift in the neighbourhood of Perth: Jour. and Proc. Roy. Soc. W.A., vol. vi., pt. I, pp. 5-29, 1919.

Aurousseau, M. and Budge, E. A.: The terraces of the Swan and Helena Rivers and their bearing on recent displacement of the strand line. Jour. and Proc. Roy. Soc., W.A., vol. vii., pp. 24-43, 1920.

found living in the Swan river, but are recorded from warmer waters farther north.

Dr. Simpson and Messrs. H. P. Woodward and M. Aurousseau sent collections from the various shell beds to the British Museum, and to the Australian Museum, Sydney, in 1920. The The work of identification was done in the latter case by Messrs Hedley and R. W. Bretnall, but there is no information regarding the author of this work in the British Museum. Dr. Simpson presented the lists from these two sources, together with some named species, to the Department of Geology, University of Western Australia. Later Messrs. J. L. Somerville and J. Cummins collected shells from the beds, and sent some species to Mr. F. Chapman, of the National Museum, Melbourne, for identification. The species so named are also in the collection of the Department of Geology. The writer has been collecting from Minim Cove, and Peppermint Grove, this work forming a portion of his course in Geology, at the University of W.A., and in addition to securing many specimens of the species previously recognised, he has found several species new to the district, for aid in the identification of which he is indebted to Mr. L. Glauert, of the Perth Museum.

The main difficulty experienced in this work has been the paucity of literature on the mollusca of this State. Hedley's paper to this Society has proved of great assistance.* Apart from this source, information regarding range has been derived from various papers in the Proceedings of the Linnean Society of New South Wales, and the Royal Societies of Queensland and South Australia. The writer also wishes to acknowledge the interest shown in his work by Sir Joseph Verco and Mr. Hedley.

It is hoped that this contribution, besides summarising the present knowledge of the sub-recent fossils of the lower Swan River District, will lead to further work on the problem of Quaternery climates in this region.

*C. Hedley: Preliminary index of the mollusca of Western Australia, Jour. and Proc. Roy. Soc., W.A., vol. i., pp. 152-226, 1914.

LIST OF SPECIES WITH LOCALITIES.

Abbreviations.

Initial after name of species indicates person responsible for identification.

C. Mr. F. Chapman.

M.—British Museum, and Mr. R. W. Bretnall, of Australian Museum.

R.—Mr. L. Glauert, Perth Museum and the writer.

Initial after locality indicates collector.

R.—J. Cummins, J. L. Somerville and the writer.

S.—Dr. E. S. Simpson, and Messrs. M. Aurousseau and H. P. Woodward.

Letter following specific localities indicates relative abundance.

r.—rare.

m.c.—moderately common.

c.—common.

x.—relative abundance not noted.

(p. 150)—Page in Hedley's Catalogue (op. cit.) "Recorded from" means "recorded living from."

Sub-kingdom MOLLUSCA.

Class LAMELLIBRANCHIATA (Pelecypoda).

Order, PRIONODESMACEA.

Arca trapezia, Deshayes (C.) *Localities*—Peppermint Grove (r.) and Minim Cove (m.c.), [R.]. *Recorded from* Sydney, North West Australia and New Guinea.

Arca fusca, Reeve (M.). *Locality*—Fremantle (x.) [S.]. *Recorded from* Cossack, Monte Bello Is., New Guinea, Thursday Island, Cleveland Bay and Murray Is. (p. 154).

Arca scapha, Chemnitz (M.). *Locality*—Peppermint Grove (m.c.), and Minim Cove (m.c.), [S.].

Arca granosa, Linn (M.). *Locality* Fremantle (x.)

Pinna virgata, Menke (C.). *Localities*—Peppermint Grove (r.) and Minim Cove (r.), [R.], (p. 155.)

Pinna phillipinensis, (M.). *Locality*—Minim Cove (r.), [S.]

Ostrea angasi, Sowerby (M.). *Localities*—Peppermint Grove (m.c.) and Minim Cove (m.c.), [R.], Perth Water (c), Melville Water (c), Canning Canal (c), Fremantle (x.) [S]. *Recorded from* King George's Sound.

Ostrea cf. cucullata, Born (C.). *Localities*—Peppermint Grove (r), Minim Cove (r.), [R.]. *Recorded from* King George's Sound and Monte Bello Island.

Diplodon, sp. (M.) [cf. *D. ambiguus* or *Unio ambiguus*—Hedley, p. 156]. *Localities*—Peppermint Grove (r.), and Minim Cove (r.), [S.]. *D. ambiguus* recorded from Canning River.

Chlamys asperrimus, Lamarck (M.). *Localities*—Perth Water (r.), Melville Water (r.), Canning Canal (r.), [S.]. *Recorded from* Swan R., Dirk Hartog, Exmouth Gulf.

Pecten medius, Lamarck (M.). *Localities*—Perth Water (r.), Melville Water (r.), [S.]. (p. 157.)

Pecten dringi, Reeve, (M.). *Locality*—Peppermint Grove (x.), [S.].

Brachyodontes erosus, Lamarck (M.). *Locality*—Rottnest (r.), [S.]—(cf *Mytilus.*) *Recorded from* Rottnest, Carnac Island, Garden Island, Geraldton and King George's Sound (p. 158).

Modiola, spp. (R.). *Localities*—Peppermint Grove (r.). Minim Cove (r.), Canning Canal (r.), [R.], (p. 159.)

Mytilus sulcatus, Lamk. (?), (M.). *Locality* Minim Cove (r.), [S.], (p. 159).

Mytilus latus, Lamarck (M.). *Locality*—Minim Cove (r.), [S.], (p. 159).

Katelysia strigosa, Lamarck (C.). *Locality*—Peppermint Grove (c.), and Minim Cove (c.), [R.].

Katelysia scalarina, Lamarck (C.). *Localities* -Peppermint Grove (c.), and Minim Cove (c.), [R.].

Order TELEODESMACEA.

Crassatellites kingicola, Lamarck (M.). *Locality*—Minim Cove (x.), [S.]. *Recorded from* Woodman's Point and Cossack (p. 160.)

Cardita, sp. (M.). *Locality* Rottnest (x.), [S.], (p. 160).

Cardita, sp. (M.). *Locality*—Melville Water (c.), [S.]. Mr. Hedley notes that this does not correspond to any recorded W.A. form and is probably a new species.

Cardium rugatum, Dillwyn (M.). *Locality*—Perth Water (c.), [S.]. (? *C. erugatum*. Tate). *Recorded from* Monte Bello Is. (p. 162).

Cardium tenuicostatum, Lamarck (M.). *Locality*—Perth Water (r.), [S.]. *Recorded from* Tasmania (p. 163.)

Cardium vertebratum, Jonas (M.). *Locality*—Minim Cove (x.), [S.].

Cardium, sp. (C.). *Locality*—Minim Cove (r.), [R.]. Mr. Chapman notes that this is probably a new species resembling ***C.***

exasperatum, but more oblique. *C. exasperatum* is recorded from Swan River.

Cardum unedo, Linne (R.). *Locality*—Minim Cove (r.), [R.]. *Recorded from* Monte Bello Is. and Thursday Is. (p. 163.)

Cardium, sp. (R.). *Locality*—Minim Cove (r.), [R.].

Soletellina biradiata, Wood (C.). *Locality*—Minim Cove (r.), [R.]. *Recorded from* King George's Sound (p. 167.).

Chama limbula, Lamarck (M.). *Locality*—Peppermint Grove (r.), Minim Cove (r.), Perth Water (c.), Melville Water (c.), Canning Canal (c.), [S.]. *Recorded from* North-West Australia (p. 161).

Chama nivalis, (M.). *Locality*—Minim Cove (x.), [S.].

Chama asperella, Lamarck (M.). *Locality*—Melville Water (x.), [S.]. *Recorded from* Sharks Bay.

Chama, sp. (M.). *Locality*—Fremantle (x), [S.].

Cryptodon globularis, Lamarck (M.). *Locality*—Minim Cove (x.), [S.]. *Recorded from* King George's Sound (p 162.)

Lasea australia, Lamarck (C.). *Locality*—Minim Cove (r.), [R.]. *Recorded from* Geraldton, Timor and King George's Sound (p. 162.)

Dosinia lucinalis, Lamarck (M.). *Locality*—Peppermint Grove (c.), Minim Cove (c.), Perth Water (m.c.), and Rottnest (x.). *Recorded from* Monte Bello Is. (p. 163.)

Dosinia sculptilis, Hanley (M.). *Localities*—Perth Water (r.), Melville Water (r.), [S.].

Dosinia, sp. A. (C.). *Locality*—Minim Cove (x.), [R.]. (Deep sub-trigonal outline and small sharp umbos separate this from known living species—C.)

Dosinia, sp. B. (C.). *Locality*—Minim Cove (x.), [R.]. (Smaller heavier build. Between *D. africana*, Gray and *D. brughieri* Gray. Smaller than the latter—found in Swan R.—and has less strongly developed ornament—C.)

Divaricella, sp. (C.). *Locality*—Minim Cove (x.), [R.] (p. 161.)

Gafrarium sulcatum, Gray (M.). *Localities*—Peppermint Grove, Minim Cove, Melville and Perth Waters (c.), [S.].

Marcia peronii, Lamarck (M.). *Locality*—Rottnest (x.), (p. 164.)

Marcia, sp. (C.). *Locality*—Minim Cove (c.) [R.].

Paphia euglypta, Phillipi (M.). *Localities*—Perth Water, Melville Water, Canning Canal (m.c.), [S.], (p. 164.)

Paphia tapes, (C.). *Locality*—Minim Cove (m.c.), [R.], (p. 164.)

Paphia, sp. (R.) *Locality*—Minim Cove (r.), [R.].

Venus (Antigona) laqueata, Sowerby [C.]. *Locality*—Fremantle (x.), (p. 165.)

Venus (Chione) strigosa, Lamarck [C.]. *Locality*—Minim Cove (x.), [R.]. (Tate records this species living from King George's Sound).

Venus (Chione) scalarina, Lamarck [C.]. *Locality*—Minim Cove (x.), [R.]. (Tate records this species living from King George's Sound).

Venus, sp. [R.]. *Locality*—Minim Cove (r.), [R.].

Venerupis carditoides, Lamarck [M.]. *Localities*—Perth Water and Melville Water (r.), [S.]. *Recorded* from Swan R. and Tasmania (p. 166.)

Venerupis planicosta, Deshayes [M.] *Locality*—Rottnest (x.), [S.]. *Recorded from* Swan R. and Tasmania.

Tellina deltoidalis, Lamarck [M.]. *Locality*—Peppermint Grove and Minim Cove (c.), [S.]. *Recorded from* Tasmania.

Tellina perna, Spengler (C.). *Localities*—Minim Cove and Peppermint Grove (c.), [R.] *Recorded from* Sharks Bay, Geraldton, Monte Bello Is.

Tellina, sp. (C.). *Locality*—Minim Cove (m.c.), [R.]. (Near *T. aldingensis*, Tate. This has shorter anterior and more rounded posterior umbonal margin than Tate's species. C.)

Tellina, sp. (C.). *Locality*—Minim Cove (r.), [R.]. Apparently ancestral to *T. deltoidalis* shorter with inflated valves—C.).

Tellina, spp. [R.] *Locality*—Peppermint Grove and Minim Cove (c.), [R.]. (Two species to be determined).

Macoma, sp. [M.]. *Locality*—Peppermint Grove and Minim Cove (m.c.), [S.].

Lucina (Codakia) cf. **simplex**, Reeve [C.]. *Locality*—Minim Cove (r.), [R.]. *Recorded from* North Australia.

Amphidesma praecisa, Reeve [M.]. *Locality*—Rottnest (x.), [S.]. *Recorded from* King George's Sound, (p. 169.)

Saxicava australis, Lamarck [M.]. *Locality*—Melville Water (r.), [S.]. *Recorded from* Cossack, (p. 169).

Nausitoria saulli, Wright (M.). *Locality*—Rottnest (x.), [S.]. *Recorded from* Fremantle and Tasmania, (p. 170.)

Class, GASTEROPODA.

Order, DIOTOCARDIA.

Clanculus denticulatus, Gray (M.). *Locality*—Perth Water (r.), [S.]—cf. *Trochus lupinus,* Philippi. *Recorded from* Geraldton, (p. 177.)

Cantharidus nitens, Kiener (M.). *Locality*—Rottnest (x.), [S.], (p. 178.)

Cantharidus cf. **conicus,** Gray (C.). *Locality*—Peppermint Grove and Minim Cove (x.), [R.]. *Recorded from* Geraldton (p. 179.)

Cantharidus, sp. (R.). *Locality* Peppermint Grove and Minim Cove (x.), [R.].

Cantharidus pulcherrimus, Wood (C.). *Locality*—Peppermint Grove and Minim Cove (x.), [R.]. *Recorded from* Geraldton, (p. 179.)

Monilea lentigenosa, A. Adams (M.). *Locality*—Perth and Melville Waters (r.), [S.]. *Recorded from* Swan R. and Sharks Bay, (p. 180.)

Calliostoma, sp. [M.]. *Locality*—Melville Water (r.), [S.], (p. 180.)

Cyclostrema tatei, Angas (M.). *Locality*—Peppermint Grove and Minim Cove (c.), [S.]. *Recorded from* Geraldton, (p. 182.)

Liotina, sp. (M.). *Locality*—Perth Water and Melville Water (c.), [S.], (p. 182.).

Liotia, sp. [M.]. *Locality*—Peppermint Grove and Minim Cove (m.c.), and Perth Water (r.), [S.].

Turbo pulcher, Menke [C.]. *Locality*—Minim Cove (x.), Fremantle (x.), [R.]. *Recorded from* Geraldton, (p. 181.)

Turbo, spp. [R.]. *Locality*—Peppermint Grove and Minim Cove (c.), [R.]. (Two species to be determined.)

Patelloida connoidea, Quoy and Gaimard (M.). *Locality*—Rottnest (x.), [S.]. *Recorded from* King George's Sound and Ellensbrook, (p. 184.)

Patelloidea altricostata, Angas (M.). *Locality*—Minim Cove and Fremantle (x.), [S.]. *Recorded from* King George's Sound, Ellensbrook, Yalingup, Esperance Bay.

Acmea aculeata, Reeve (M.). *Locality*—Fremantle (x.), [S.].

Acmea scalarina, Cox sp. (M.). *Locality*—Peppermint Grove and Minim Cove (x.), [S.]. *Recorded from* Geraldton (p. 188).

Patella zebra, Reeve (M.). *Locality*—Fremantle (x.), (p. 185.)

Order, MONOTOCARDIA.

Bembicium melanostoma, Gmelin (M.). *Locality*—Minim Cove and Rottnest (x.), [S.], (*Trochus—Rissella*), (p. 187.)

Obtortio lutosus, Hedley (C.). *Locality*—Peppermint Grove and Minim Cove (m.c.), Perth and Melville Waters (c.), [R.]. *Recorded from* Sydney and Hope Is., Q.

Rissoina sp. (C.). *Locality*—Minim Cove (r.), [R.], (p. 187.)

Bullinella arachis, Q. & G., (C.). *Locality*—Minim Cove (x), [R.]. *Recorded from* King George's Sound.

Diala lauta, A. Adams (M.). *Locality*—Peppermint Grove and Minim Cove (m.c.), [S.]. *Recorded from* King George's Sd. and Geraldton, Port Adelaide and Tasmania, (p. 188.)

Diala translucida, Hedley (C.). *Locality*—Minim Cove (x.), [R.]. *Recorded from* N.S.W., (p. 188.)

Diala, sp. (M.). *Locality*—Perth and Melville Waters (c.), [S.].

Hipponix antiquata, Linne (M.). *Locality*—Fremantle (x.), [S.]. *Recorded from* Geraldton, (p. 189.)

Alaba, sp. (M.). *Locality*—Perth and Melville Waters (m.c.), [S.]—**A. vitex,** Adams—*recorded from* Sharks Bay.)

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(Lat. S. and Long E.).

SUMMARY AND CONCLUSIONS.

Of the 129 species listed in the last section, record of the geographical distribution of 56 only has been found by the writer. Of these 56, 22 have not been found south of Geraldton, 17 are of wide range and 17 are not recorded north of Geraldton. From these figures it would seem that there is a balance of evidence in favour of recent cooling of the water in the latitude of Perth.

Since reading this paper the writer has noticed the occurrence of fairly well defined fossiliferous zones in the shell beds, and a broad observation of the fauna in these zones has led to the opinion that in all probability there has been alternation of warm and cool waters during the deposition of the beds. This point would form the basis of profitable investigations in the district, and the matter of Quaternary climates be, thus, further cleared up.

The writer would like to state in conclusion, that criticism of this paper, more particularly of the nomenclature and classification, will be welcome.

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A Preliminary Census of the Plant Diseases of South-Western Australia.

By **W. M. Carne, F.L.S.**, Economic Botanist and Plant Pathologist, Department of Agriculture, Perth.

(*Read* March 10, 1925. *Published* June 20, 1925).

Records of the occurrence of plant diseases in Western Australia are scattered through various publications. The present paper is an attempt to bring them together, with a number not previously published. It is hoped that it may serve as a contribution to a census of the plant diseases of Australia.

The most comprehensive list of diseases recorded as occurring in Western Australia published up to the present time is to be found in McAlpine's Systematic Arrangement of Australian Fungi, 1895. The writer has, however, considered it advisable to omit some of the references therein given, while others have been somewhat doubtfully included. These remarks apply to important diseases of economic plants which are unknown to the field officers of this Department and to the writer. If they do occur they are certainly not of economic importance in this State. Such diseases include Apply Scab (*Venturia inequalis*), Leaf Rust of Wheat (*Puccinia triticina*), etc. Records in early publications of the Department of Agriculture are also omitted where they do not bear evidence of reliable identification, unless the diseases have been personally seen by the writer. It may, therefore, be stated that all diseases listed and not rcorded by recognised authorities have been seen by him. Where no authority is quoted the record is apparently a new one.

The list does not pretend to be exhaustive, and several known diseases, not yet determined with any certainty, have been omitted. It is intended to publish additional records from time to time. An attempt has also been made to indicate appromimately the season of occurrence and the relative importance of the diseases of economic plants.

The writer desires to gratefully acknowledge the assistance given by officers of the Department of Agriculture, more particularly Mr. J. G. C. Campbell, B.Sc., formerly Assistant Botanist, and Messrs. Wickens, Lowe and Larwood.

SOUTH-WESTERN AUSTRALIA.

The area under consideration practically covers that designated as Swanland by Professor Griffith Taylor. The South-West being a term used in several senses, for clearer definition the area referred to will be called Swanland in this paper. It forms a triangular area extending from the Murchison River to a little East of Esperance. The base of the triangle is formed by the 10 inch isohyet, the other two sides to West and South being bounded by the ocean. This base line represents roughly the Eastern limits of Agriculture. Though outside the area, places, such as Kalgoorlie, on the Goldfields Water Scheme are included in respect to the diseases of cultivated plants.

CLIMATE AS AFFECTING THE OCCURRENCE OF DISEASES.

The climate of Swanland has been well described by Professor Griffith Taylor* in general terms. More detailed information is to be found in articles by W. Catton Grasby† with particular application to the area south of Perth and west of the Great Southern Railway.

The climate is of the Mediterranean type. The summers are warm and dry, the winters mild and the rainfall practically confined to the cooler months of the year. "The rainfall is the least variable in Australia. Hence it is possible to grow wheat with a lower average rainfall than elsewhere, especially as the rain falls just in that season when it is most required."* The variation of the annual rainfall from the average rarely reaches 10 % between Perth and the Leeuwin. From Geraldton to the extreme South-Easterly point the variation for some distance from the coast does not exceed 15 %, while over the whole area, including the Eastern Wheat Belt, the rainfall does not vary more than 20 %. The maximum falls occur on the average in June and July. The average annual falls vary from about 50 inches in the extreme South-West to 10 inches on the eastern boundary of the area. The summer rainfall is erratic, but is never great, averaging about 8 % to 10 % of the total fall during the period November to March, with a variation of 6 % to 17 % according to locality, the greater percentage occurring in the extreme South-West. Fruit trees and vegetables are grown principally between the 25 inch isohyet and the sea, while sown pastures and miscellaneous summer crops extend to about the 20 inch isohyet. The principal cereal areas are between the 25 inch and

* Griffith Taylor, The Australian Environment. Advisory Council of Science and Industry. Memoir 1. Melbourne, 1918.

† W. Catton Grasby. The Climate of the South-West. "Western Mail," Perth, 10th July, 1924. Also Handbook and Guide to W.A. Govt. Printer, 1914, pp. 28-30.

10 inch isohyets, though oats and to a lesser extent wheat are grown under the higher rainfalls. As regards temperatures, the summers are hot, the maximum temperatures rising northwards and eastwards. The nights are usually cool. The south or south-easterly summer sea breezes which arise about midday on the coast and eventually carry their effects 150 miles or so inland are a great aid to human comfort. In the South-West the nights in summer may be quite cold, especially away from the coast. (See records for the summer of 1924 at Bridgetown under Apple Bitter Pit.) There is a distinct absence of mugginess except on rare occasions in the summer. The winters are mild. Damaging frosts are rare towards the coast. Further east the frosts are more severe, but there crops such as fruits and vegetables which are likely to suffer are not largely grown.

In so far as the capital cities may be taken as representative of their several States, comparisons are interesting. It will be noted in the following tables compiled from the Commonwealth Year Book that Perth has more hours of sunshine and fewer rainy days in the summer (November-March), and ranks second to Adelaide in lowness of summer humidity.

RELATIVE HUMIDITY (%) OF SUMMER MONTHS.*

Mean Daily Highest Readings.

	Perth.	Adelaide.	Melbourne.	Sydney.	Brisbane.
November	63	57	69	79	72
December	62	50	69	77	68
January	61	59	65	78	79
February	65	56	69	81	82
March	66	58	71	85	85
Average for 5 summer months	63	56	69	80	77
Mean 9 a.m. readings	54	41	60	70	67

AVERAGE NUMBER OF RAINY DAYS.*

	Perth.	Adelaide.	Melbourne.	Sydney.	Brisbane.
November to March ..	19	28	43	68	65
April to October	100	95	93	88	64
Total	119	123	136	156	129

* Compiled from Official Year Book. Commonwealth of Australia. No. 16. Melbourne, 1923.

AVERAGE YEARLY HOURS OF SUNSHINE.*

	Perth.	Adelaide.	Melbourne.	Sydney.	Brisbane.
November to March	1,476	1,380	1,245	961	1,107
April to October ..	1,111	1,063	1,161	1,328	1,458
Total	2,586	2,443	2,406	2,289	2,565

From the point of view of plant growth the year may be conveniently divided into two periods, the dry and the wet. The latter may be divided again into autumn, winter, and spring.

Dry: Summer—November to March.
Autumn—April and May.

Wet: Winter—June, July, and August.
Spring—September and October.

The foregoing is only approximate, as the wet season may commence or conclude earlier or later by several weeks, thus not only affecting to some extent the whole length of the wet season, but considerably altering the length of the autumn and spring portions. The dry season, except perhaps in the extreme South-West, has no dependable summer rain. What does occur is in the form of thunderstorms, which are erratic and more or less local and short-lived. They may do more harm than good to plant growth by stimulating the germination of the seeds of annual plants, which shortly after fail from lack of moisture, and thus reduce the possible autumn germination of herbaceous plants. The summer season is responsible for plant troubles, which are primarily those of water supply. These are to be found in stunted growth, dropping of leaves, dieback of younger growth, etc. Troubles due to excess of sodium chloride, sodium and magnesium sulphate are also more marked towards the end of summer, as these salts become concentrated by capillarity and evaporation in the surface layers of the soil. The drying effects of strong east winds and the mechanical effects of the same winds when sand-laden, must also be here included. Close to the coast the salt-laden summer sea breezes (''Doctors,'' as they are usually called, as ''Fremantle Doctor,'' ''Geraldton Doctor'') have a marked detrimental effect on exposed plants. This effect also results from the strong south-west winter blows. The occurrence of cool nights approaching freezing point in the summer in the South-West may be associated with the development of Bitter Pit in apples. Summer rains at critical periods may cause cracking of ripening fruits, e.g., apples, grapes, oranges. With citrus fruits the same result may occur with the opening

* Compiled from Official Year Book. Commonwealth of Australia. No. 16. Melbourne, 1923.

of the wet season in orchards which have not had, naturally or by irrigation, sufficient moisture during the summer. It is possible that similar causes associated with poor gravelly soils are connected with the occurrence of Exanthema of citrus. Another trouble, associated apparently with rapid changes of water supply, is the Blossom-end Rot of tomatoes, which occurs on light soils. Delicate plants grown in sandy soils may be injured owing to the heating of the sand by the sun.

As regards parasitic diseases attacking above ground parts, few occur primarily in the summer. The majority then found may be traced back to infection in the wet season. It is interesting to note here the effect of the sea breezes on the atmospheric humidity. Almost every day in summer a breeze commences at the coast about midday, and finally makes itself felt upwards of 150 miles inland. It is accompanied by a rise in humidity, so that readings show a general increase at Perth from midday to midnight, and then fall again. Its arrival in the wheat belt results in a toughening of the straw of the crop, and in reducing the efficiency of harvesting machinery, frequently requiring a cessation of work. Nevertheless, this increase in humidity coincident with high temperatures appears to play no important part in the occurrence of disease. Wheat is grown within two or three miles of the sea at Dongarra, and quite close throughout the Midland and Geraldton areas generally. Yet rust, though always present in unimportant quantities, is only of importance in the rare years of very wet springs followed by warm, cloudy or foggy weather.

Summer crops are dependent upon natural supplies of soil moisture, such as occur on river flats and in depressions supplied by soakage, or upon irrigation. To a lesser extent they may be grown on water retained in the soil by cultivation and fallowing. In these ways vegetables, fruits, and crops, such as lucerne, Sudan grass, sorghum and maize, etc., and early sown crops of oats, are able to be grown. The term "summer land" is used to indicate soils naturally well supplied with moisture in the summer. Such soils unless drained are usually more or less inundated in the winter, and are then useless for crops. When properly drained, cultivation is possible throughout the year. Irrigation is confined to a scheme at Harvey and to individual pumping or gravitational systems. In the goldfields area the cultivation of vegetables and gardens is rendered possible from the water from the Goldfields Water Supply. In the Metropolitan area, and where public water systems are available, these are used to a small extent for vegetable crops in the summer.

The low humidity is a great protection for summer crops against parasitic diseases of the above ground parts. This protection is less effective where spray irrigation is used, the wetting of the plants being probably the principal reason. There is

naturally not the same protection against diseases which attack plants at or below ground level.

The wet season with its two growing periods, the autumn and spring, is, in consequence of its high humidity, the season in which parasitic diseases are most important. As in one case the temperatures are falling and in the other rising, it naturally follows that serious occurrences of disease are most likely in wet seasons which open early or close late, so that high humidity coincides with relatively high temperatures. Again for the same reason epiphytotisms are more likely in the spring with rising temperatures and increasing development of the parasites than in the autumn with falling temperatures. Diseases which are normally spring-infecting such as Mildew of Grape (*Uncinula necator*), Black Spot of Grape (*Sphaceloma ampelina*), Scab of Pear (*Venturia pyrina*), Leaf Curl of peaches and nectarines (*Taphrina deformans*), etc., are to be expected in important occurrence whenever the wet season continues unusually late.

It appears probable that the occurrence of autumn-infecting diseases, such as Ball Smut (*Tilletia levis*), Take-all (*Ophiobolus graminis*), and Flag Smut (*Urocystis tritici*) are most likely to be serious with the occurrence of an early wet season. This is in accord with general experience, which indicates that these diseases are less likely to occur in seasons of late autumn rains.

The foregoing remarks do not apply to those diseases which are favoured by relatively low temperatures combined with high humidity. Such diseases may be serious from the autumn to spring. For instance, Brown Rot of orange (*Phytophthora sp.*) may start at any time in the wet season and reach its maximum development about August, coinciding with the ripening of the fruit.

Diseases of non-parasitic character occurring in the wet season are usually connected with water supply and low temperatures. The water-logging of soils is important in this direction, especially when followed by warm dry periods in which heavy soils set hard. Dry warm spells in winter may be responsible for the premature flowering of cereal crops, resulting in damage from drought or from subsequent rain or frosts. The occurrence of cold spells after the spring has commenced may also interfere with fruit setting, and appears to be associated with the occurrence of Sour Sap in apples and stone fruits.

In general it may be stated the crops in Western Australia, owing to the low summer humidity are very free from above ground parasitic diseases in the summer. The occurrence of such diseases as occur may be traced back to infection in the spring, during which time the resultant damage has its origin. It is probable that little infection or re-infection of plants occurs once the dry season has started.

Parasitic diseases more definitely developed in the spring or

autumn are not uncommon, but their important occurrence appears to be largely connected with unusual earliness or lateness of the wet season or the occurrence of muggy weather in the summer.

The occurrence of diseases due to pathogenic organisms, such as Fuharium spp., attacking from the soil is determined more by soil moisture than atmospheric humidity. Such diseases may occur at any time during warm weather.

Parasitic diseases favoured by cool moist weather find ideal conditions in the late autumn and winter and early spring months. Fortunately few in number, these diseases are frequently serious.

Storage diseases due to saprophytes and weak parasites such as *Fusarium, Alternaria, Macrosporium, Penicillium*, etc., are able to develop whenever the suitable moisture conditions are available. Temperatures, except in cool storage, are rarely low enough to stop their development, which is naturally greatest and most serious at high temperatures.

Diseases of a non-parasitic nature are in the main climatic in origin, being principally connected with moisture supplies and temperature, and evaporation due to wind and dry air. These troubles, together with those due to soil conditions, are to be foreseen to a large extent, and may be judiciously avoided or guarded against. Their occurrence is usually the outcome of the selection of unsuitable sites or the failure to arrange for the necessary moisture for summer crops, protection from wind, drainage, etc. This remark does not apply, of course, to troubles arising from unseasonable conditions.

Several important diseases occurring in the other Australian States are absent or rare. They are principally those requiring warm muggy conditions in spring and summer for their best development. Amongst those which are not known are Apple Scab (*Venturia inequalis*), and Downy Mildew of Grape (*Plasmopora viticola*). Amongst those that are rare are Irish Blight of potatoes (*Phytophthora infestans*), Wheat Rust (*Puccinia graminis*), and Brown Rot of stone fruits (*Monilia* sp.)

It is an interesting sidelight on the occurrence of these diseases that systematic spraying in orchards is limited to the winter and spring months. Summer spraying of fruits is almost unknown.

ISOLATION AS A FACTOR AFFECTING THE INTRODUCTION OF DISEASES.

The isolation of Western Australia by a wide belt of arid uncultivated country from the other States and from the North-West, has undoubtedly been of assistance in keeping out some of the parasitic diseases. It follows that all plants, seeds, etc.,

likely to convey diseases can only enter the State at relatively few points. The great bulk of imports come through Fremantle, the remainder through Albany and Kalgoorlie and per medium of the Post Office. Outside these usual channels in which all imports are subject to inspection, there remains only the danger of introduction in the personal baggage of travellers, via Fremantle, Albany, and Kalgoorlie.

LEGISLATION AND INSPECTION AS RELATED TO THE INTRODUCTION OF DISEASES.

Inspection of all plants, seeds, etc., both from abroad and from other States is carried out under either the Federal Quarantine Act or the State Plant Diseases Act. The scope of the latter in particular is very wide. Undoubtedly this inspection has been instrumental in checking many introductions of disease, particularly those of apples, the importation of which is wholly prohibited. Western Australia imports large quantities of seeds, including cereals, and also orchard plants. Very little is imported in the way of fruit, except dried and tropical fruits, but considerable imports are made of potatoes. The defects of inspection as a preventive against parasitic diseases are obvious. Many diseases cannot be recognised in a practical way on seeds, tubers or plants. Diseases known only in recent years in this State and probably introduced on seed include Downy Mildew (*Sclerospora macrospora*), and Flag Smut (*Urocystis tritici*) of wheat. The Plant Diseases Act provides ample power to deal with an outbreak of a new disease, but it is usually the case that the occurrence is not reported for several seasons, during which the disease becomes established and eradication becomes economically almost impossible.

Summary.—Western Australia is very free from parasitic diseases that are normally summer diseases. It is subject slightly to diseases which cause infection in the spring, but reach their obvious development in the summer. It is subject more seriously to diseases which are primarily of autumn, winter and spring occurrence, to diseases due to infection from the soil, and to those caused by organisms which thrive at low temperatures. It is also liable to a number of plant troubles from environmental conditions, especially those arising out of the climate. In short, plants in Western Australia are liable to parasitic diseases in the wet season and to non-parasitic troubles in the dry season.

PLANT DISEASES OF WESTERN AUSTRALIA.

In the following table—

Occurrence is indicated by—

V.C. = Very common.

C. = Common.

O. = Occasional, though found to some extent each year.

R. = Rare. Only occasional years.

Importance in cases of maximum attack noted.—

4. = Very serious, leading to crop failures, or serious wastage in products.

3. = Serious. Control treatment advisable.

2. = Not serious. Control treatment not usual.

1. = No economic importance.

Season of occurrence.—

W. = Wet season (April or May to September or October).

W (spring) indicates the period September-October or to conclusion of wet season.

D. = Dry season (October or November-March or April).

The first published record of the occurrence of a disease in Western Australia is indicated by the recorder's name and date of publication as shown in the Bibliography attached.

The table is compiled on a host basis. Exotic plants are grouped; native plants are in alphabetical order of botanical names.

FRUIT AND FRUIT TREES.

POME FRUITS.

(Apple, Pear, and Quince.)

Mildew. *Podosphaera oxyacanthae* (DC) De Bary. VC. 3. W (spring). Despeissis 1901, on apples. Occurs also on pears. Apple varieties most affected are Northern Spy, Rome Beauty, and Cleopatra.

Pear Scab or Black Spot. *Venturia pyrina* Aderh. VC. 3-4. W (spring) & D. McAlpine 1895.

Root Rot. *Armillaria mellea* (Vahl) Quel. O. 3-4. W & D. Found principally where the trees were planted after clearing green timber, especially on land which had carried Marri (Eucalyptus calophylla).

Stem Canker. *Diplodia* sp. Causes a twig dieback and cankering of stems of apples and pears. Not known on fruit. Recorded only from Capel from a non-commercial orchard. Carne 1924.

Blister Canker. Associated with *Coniothecium* sp. C. 1-4. W & D. Carne 1924. On apple and pear trees, particularly those affected with fruit cracking. Twigs die back. Bark of stems develops large blistered areas. Probably physiological in origin. Locally known as Fire Blight. Dieback is most marked on pear trees on Darling Range. Leaves appear burnt.

Fruit Russetting and Cracking. Frequently associated with *Coniothecium* sp. O-C. 1-4. W (spring) & D. Carne 1924. Probably physiological in origin and varies with the seasons. Bad 1923-24 with an early dry season. Rare 1924-25 with a late and cool summer. Locally known as Scab. Dunns, Pippins, Rokewood, and other hard varieties of apples are very subject. Pears are usually less affected.

Fruit-Cracking Non-parasitic. O. 3-4. D. Due to effects of summer or unusually early autumn rains on ripening fruit.

Bitter Pit, Crinkle, Pig Face. Non-parasitic. O-VC. 3-4. D. McAlpine 1912. On apples and pears. Varies considerably from season to season. Occurred badly during 1923-24 season, which was characterised by hot days and cool nights. Varieties most affected are Cleopatra, Cox's, Jonathan, Rome Beauty, etc. Occurs also as a cold storage and shipping trouble. The 1923-24 season was one of the worst known for this disease, as well as the driest summer on record. It is interesting to note the temperatures* recorded at two of the principal apple-growing centres:—

	Bridgetown.				Mt. Barker.		
	Min.	Max.	Greatest daily range.		Min.	Max.	Greatest daily range.
1923.							
December	39.0	94.5	47.3	..	41.0	91.0	39.1
1924.							
January	37.0	102.0	52.0	..	40.0	102.0	45.0
February	37.5	96.5	49.0	..	44.1	99.8	42.7
March	35.0	91.0	52.5	..	44.8	93.0	36.7
April	35.0	95.0	53.0	..	43.0	90.0	29.7

Jonathan Spot. Non-parasitic. O. 3. D. Though infrequent on trees, is very common on stored Jonathans, occasionally on other varieties such as Rome Beauty.

Sour Sap. Non-parasitic. O. 3-4. W (spring). Varies considerably with the seasons and is very local in occurrence. Appears to be favoured by a season when a cold spell occurs after spring growth has commenced, especially in moist situations.

Brown Heart. Non-parasitic. Known principally as a ship-

* Kindly supplied by Mr. E. B. Curlewis, Officer-in-Charge, Commonwealth Meteorological Bureau, Perth.

ping and cold storage trouble. Varies considerably with different shipments. Not reported as occurring in shipments in 1924.

Internal Breakdown. Non-parasitic. Cold storage trouble.

Scald. Non-parasitic. Cold storage trouble.

Water or Glassy Core. Non-parasitic. O. 1. D. Varieties principally affected are Stone Pippin, Dunn and Rokewood.

Mouldy Core. Saprophytic fungi? O. 1. D. Common in varieties with open calyx-ends, as Cleopatra.

Chlorosis. Non parasitic. C. 1. D. Jonathans are especially subject.

STONE FRUITS.

(Peach, Plum, Apricot, Cherry, Almond, Nectarine.)

Leaf Curl of Peach and Nectarine. *Taphrina deformans* (Fel) Tul. VC. 3-4 W (spring). McAlpine 1895. Varieties of peaches most affected are Elberta, Lady Palmerston and China Flat. The disease occurs occasionally on nectarine fruits.

Rust. *Puccinia pruni-spinosae* Pers. VC. 1. D. McAlpine 1895. Occurs in summer and late autumn on leaves and very rarely on fruit. Royal George is probably the most affected peach. Fruit attack is practically confined to late seedlings. Peach, almond and plum attacked.

Apricot Blossom Wilt and Dieback. *Monilia* sp. R. 34. W. (spring). Known only from one locality in Upper Swan.

Root Rot. *Armillaria mellea* (Vahl) Quel. O. 3-4. W and D. See note under Pome Fruits.

Shot Hole. *Phyllosticta circumcissa* Cke. O. 2. D. McAlpine 1895.

Shot Hole or Dieback. *Clasterosporium carpophilum* (Lev) Aderh. C-VC. 2-4. W (spring) & D. Bad on apricots, but especially so on almonds in the coastal districts. Less common on peach and plum.

Sour Sap. Non-parasitic. O. 4. W (spring). Jnl. Bur. Agr. W.A. 1896, p. 1027 and p. 1049. Seasonal variation particularly marked in stone fruits. See also note under Pome fruits.

Gummosis. Non-parasitic? O. 2-4 D. Serious on cherries.

Jap. Plum Deformity or Crinkle. Non-parasitic. O. 3. D. Found principally on Kelsey plums. Causes depressed firm irregular areas resembling confluent Bitter Pit in apples. Tissue firm and dark, but not dry as in apples.

CITRUS FRUITS.

(Orange, Lemon, Mandarin, Grapefruit.)

Australian Brown Rot of Orange. *Phytophthora* sp. C. 4. W. Carne 1924. This disease is widely spread, but is much more serious in the Darling Range orchards than on the coastal plain. Causes also a leaf blight.

Australian Lemon Brown Rot. *Phytophthora* sp. C. 4. W. Carne 1924.

Lemon Leaf Blight (caused by an unidentified Phycomycete). C. 4. W. Carne 1924.

Sooty Mould. *Capnodium citricolum* McAlp. C. 3. D. McAlpine 1899. Closely associated with the occurrence of Lecanium Scales and Aphides.

Root Rot. *Armillaria mellea* (Vahl.) Quel. O. 3-4. W. & D. J. S. Jefferson 1907. Citrus trees are very subject to attack. See note under Pome fruits.

Withertip or Dieback. *Phoma omnivora* McAlp. W. & D.. McAlpine 1899.

Withertip or Dieback. Associated with *Colletotrichum gloeosporoides* Penz. VC. W or D. Fungus always to be found on sickly branches or leaves. Associated with, but probably not an original cause of Dieback. Also occurs as a storage disease of fruit occurring with *Penicillium* spp. following Brown Rots. Common on stem nipples on stored fruit.

Scurf of Fruits. Associated with *Sporodesmium* sp. VC. ?. W. & D. This fungus is usually associated with scurf on citrus fruits, but appears in the main to be secondary to skin injuries due to scratches, rubbing, insect bites, etc. Probably enlarges the affected area.

Black Rot. *Cladosporium* sp. C. W. Secondary. Common on lemons with Brown and Sour Rots. Less common on oranges with Brown Rot, etc.

Botrytis Rot. *Botrytis cinerea* Pers. Recorded from Harvey only. O. 4. W.

Other Rots. *Alternaria* sp. and *Fusarium* sp. O. ?. W. Occasionally associated with other rots of citrus fruit.

Blue and Green Moulds. *Penicillium italicum* Weh. and *P. digitatum* (Fr.) Sacc. VC. 4. W. The most serious storage disease following injury to fruit, Brown Rot, etc. Occurs on fruit on trees, but principally on soil or in packing sheds and stores.

Sour Rot or Watery Rot of Lemons. *Oospora citri-aurantii* (Ferr.). Sacc. and Syd. VC. 4. W. Very common on lemons

affected with Brown Rot. Probably always secondary. Fruit rots on trees or in store, producing a soft greasy watery rot with a characteristic acid smell. The fruit develops a straw colour, and is very liable to split open. Has been found associated with Brown Rot on oranges occasionally.

Leaf Spot. *Septoria Westralensis* McAlpine. Recorded by McAlpine, 1899. Not seen by writer.

Collar Rot. ?*Fusarium limonis* Bri. O. 2. W & D. Occurs in wet and badly drained spots, and especially on lemons.

Exanthema. Non-parasitic. C. 4. W. Especially on light and gravelly soils.

Mottled Leaf. Non-parasitic. C. 1. D & W. Generally regarded as evidence of nutritive troubles.

Leaf Scab or Greasy Spot. Non-parasitic. O. 1. D & W.

Stem-end Spot. O. 3. W. Non-parasitic. Occurs on Oranges, especially Navels, kept too long after picking.

Crinkle of Orange. Non-parasitic. O-C. 1-2. This name is applied to the cracking of the pithy portion of the skin resulting in depressions on the surface. The quarters are sometimes ruptured and cells protruded into the cracks. May lead to splitting in cased oranges. When oranges split on the trees after summer rains the ruptures tend to follow the crinkles. Occurrence varies considerably with the seasons. Appears to be worst in orchards which have become dry from lack of sufficient summer irrigation.

Fruit Splitting. O-C. 4. D. Due principally to summer rains after the dry season has become well advanced.

GRAPES.

Powdery Mildew or Oidium. *Uncinula necator* (Schw.) Burr. Perithecia not seen. VC. 3-4. W (spring). McAlpine 1895.

Anthracnose, Black Spot. *Sphaceloma ampelinum* De Bary. VC. 3-4. W (spring) and D. McAlpine, 1895. Principally in the coastal districts. The newer inland vineyards are free from this disease.

Root Rot. *Armillaria mellea* (Vahl) Quel. O. 3. W & D. See note under Pome Fruits.

Court-Noue. Non-parasitic. O. 4. W. (spring). In limited areas in Swan and Spearwood districts. Severity varies with the seasons. Cause unknown.

Coulure or Shedding. Non-parasitic. Varies with seasonal conditions.

Chlorosis. Non-parasitic. C. — D.

Sun Scald. Non-parasitic. O. 1-2. D. Varies in importance with the seasons.

Lightning Injury. R. —. D. Two cases recorded in the Swan district.

Fruit Splitting. Varies with season. Associated with the occurrence of summer rains when fruit is ripening. Followed by moulds.

MISCELLANEOUS FRUITS.

Fig: Leaf Mottle, Fruit Splitting and Dropping. Cause unknown, probably due to soil moisture conditions. VC. 2-4. W.D.

Fig: Eelworm. O. W & D. Common around Perth and Fremantle, on sandy soils.

Loquat: Anthracnose. *Fusicladium eriobotryae* Cav. VC. 3 W. (spring). Despeissis, 1901.

Mulberry: Root Rot. *Armillaria mellea* (Vahl) Quel. O. 3. W & D. See note under Pome Fruits.

Mulberry Leaf Spot. *Bacillus mori* B. & L.? O. 3-4. D. Fairly common on edible mulberries around Perth.

Passion Fruit: Root Rot. *Armillaria mellea* (Vahl) Quel. O. 3. W & D.

Passion Fruit: Brown Spot. *Gloeosporium fructigenum* Berk. Recorded only from Coolup, 1924.

Passion Fruit: Eelworm. *Heterodera radicicola* O. D.

Strawberry: Mildew. *Sphaerotheca humuli* (D.C.) Burr. O. 2. W.

Strawberry: Leaf Spot. *Mycosphaerella fragariae* (Schw.) Lind. VC. 2. D. McAlpine, 1895.

VEGETABLE CROPS.

Potato.

Black Leg. *Bacillus atrosepticus* Vann Hall. O. 2. W. (spring). Herbert, 1920.

Bacteriosis. Bacterial Wilt. *Bacillus solanacearum* E.F. Sm. O. 2-3. W & D (spring). Herbert, 1920.

Wet Rot. *Bacillus* spp. O. 3-4. W & D. Rotting of tubers after harvesting. Most serious in autumn crop when early autumn rains in swamp land makes harvesting in wet soils necessary.

Scab. *Actinomyces scabies* (Thax.) Gussow. V.C. 3. W & D. Helms, 1898. Principally in summer crops in heavy sour soil which is waterlogged in winter.

Irish Blight. *Phytophthora infestans* (Mont) De Bary. R. 4. W (spring). McAlpine, 1911. No serious damage since 1918.

Rhizoctonia Scab. *Corticium vagum* B. & C. var. solani Ber. C. 2-3. W & D. McAlpine, 1911.

Root Rot. *Armillaria mellea* (Vahl.) Quel. R. 1. D & W. See note under Pome Fruits.

Silver Scurf or Storage Trouble. *Spondylocladium atrovirens* Harz. C. 2-3. W & D (spring and autumn). Noticeable principally on stored potatoes.

Early Blight. *Alternaria solani* (E and M) Jones and Grout. O. 2-3. W (spring). Herbert, 1920. Fairly common in June planted crops.

Wilt, Dry Rot or Brown Ring. *Fusarium* (*oxysporum* Schl.?) O. 2. W & D. Herbert, 1920.

Storage Rot. *Fusarium* sp. C. 3. W & D. Common on injured and diseased tubers.

Eelworm. *Heterodera radicicola* (Greef) Mull. O. 2-3. D. Newman, 1920. Localised in various places. Prevalent on irrigated crops at Hamel. Not known in more important potato areas.

Hollow Heart. Non-parasitic. R. 1. D & W. Herbert, 1920.

Black Heart. Non-parasitic. R. 4 A storage trouble due to lack of ventilation.

Brown Fleck. Non-parasitic. R. 2. D. Herbert, 1920. Principally in irrigated crops.

Thready Eye. Non-parasitic. R. 4. D. Herbert, 1920. Principally in Albany district in April dug crop.

TOMATO.

Bacteriosis or Bacterial Wilt. *Bacillus solanacearum.* E.F. Sm. O. 4. D.

Leaf Spot. *Septoria lycopersici* Speg. C. 2. D. On early crops only.

Early Blight. *Alternaria solani* (E & M.) Jones and Grout. C. 2. D. On early crops only.

Blossom-end Rot or Black Spot. Non-parasitic, associated with *Alternaria* sp., etc. C. 4. D. On dry soils, especially sand and heavy clays. Chalks Early Jewel particularly subject.

Sleepy Sickness or Wilt. *Fusarium lycoperscici* Sacc. O. 4. D. Carne, 1923 (Bulletin on Spotted Wilt).

Eelworm. *Heterodera radicicola* (Greef) Mull. O. 2. D. On dry sandy soils.

Spotted Wilt or Tomato Disease. VC. 4. W & D. Cause unknown. Has severely affected the commercial growing of early tomatoes, and has completely prohibited that crop around Perth. The late summer and autumn crops are much less but still seriously affected. Northern and inland districts are relatively free, but of these only Geraldton produces early tomatoes in commercial quantities. Carne, 1923.

Sunburn of Fruit. Non-parasitic. O. 2-3. D. On dry soils particularly.

Rosette or Hen and Chickens. Non-parasitic. O. 4. D.

BEANS.

Broad, French and Runner.

Anthracnose of French Beans. *Glomerella lindemuthianum* Shear. C. 2. D. Despeissis, 1901.

Rust of Broad Bean. *Uromyces fabae* (Pers) De Bary. C. 1. W.

Red Leaf Blotch of Broad Bean. Cause unknown. C. 2. W.

PEAS.

Mildew. *Peronospora viciae* Berk. Recorded only from Beverley, October, 1924.

Leaf Spot. *Mycosphaerella pinodes* (Berk & Blox) Lind. O. 2. W.

Eelworm. *Heterodera radicicola* (Greef) Mull. C. 2-3. Usually associated with dry soils in the autumn.

BEETS AND MANGOLDS.

Heart Rot. *Mycosphaerella tabifica* (Prill & Del.) Johns. C. 2. W.

Leaf Spot. *Cercospora beticola* Sacc. C. 1. W.

Rust. *Uromyces betae* (Pers) Kuehn. O. 1. W.

Eelworm. *Heterodera radicicola* (Greef) Mull. C. 2-3. D. Important only at the end of summer in drying soils.

CELERY.

Late Blight. *Septoria petroselini* Desm. var. apii Br. & Cav. VC. 3-4. W (spring) & D. Principally in spring crop. Occurs to a lesser extent in autumn and late summer. Grown on drained swamp lands.

CARROT AND PARSNIP.

Eelworm. *Heterodera radicicola* (Greef) Mull. C. 3. D. May be bad at the end of summer if the soil dries out.

CABBAGE, CAULIFLOWER, SWEDE, TURNIP, Etc.

Club Root. *Plasmodiophora brassicae* Wor. R. 2. D.

Black Rot of Cabbage and Cauliflower. ? *Pseudomonas campestris* Pam. O. 3-4. D & W. Autumn and Spring.

Ring Spot of Cabbage and Cauliflower. *Mycosphaerella brassicicola* (Duby) Lind. C. 2. W.

Black Leg of Cabbage and Cauliflower. *Phoma brassicae* Thuem. Found near Fremantle in autumn, 1924, associated with Black Rot.

Eelworm. *Heterodera radicicola* (Greef) Mull. O. 2. D. Autumn and spring.

MELON, PUMPKIN, SQUASH, CUCUMBER, Etc.

Mildew. *Erysiphe cichoracearum* DC. VC. 2-4. D.

Anthracnose. *Gloeosporium* sp. O. 2-3. D.

Tip Rot of Fruit. Non-parasitic. C. 2. D.

Eelworm. *Heterodera radicicola* (Greef) Mull. O. 3. D.

ONION, LEEK AND SHALLOT.

Mildew. *Peronospora schleideni* Ung. VC. 2. W (spring) & D. Usually appears as crops are maturing. Herbert, 1919.

Red Root. *Fusarium* sp. (?*F. malli* Taub). VC. 3. W. Mainly around Spearwood, the principal onion district. Becomes most noticeable in spring, but occurs in seed beds in autumn. Herbert, 1921, without identification of parasite.

Bulb Rot. *Fusarium* sp. Recorded from Peel Estate and Hamel, August and September, 1924.

Eelworm. *Heterodera radicicola* (Greef) Mull. O. 1. D.

RHUBARB.

Crown Rot. *Phytophthora* sp. O. 4. D.

Root Rot. *Armillaria mellea* (Vahl) Quel. O. 3.

Rust. *Puccinia phragmites* (Schum) Koern. VC. 1. D & W.

Leaf Spot. *Phyllosticta* sp. C. 2. D & W.

Eelworm. *Heterodera radicicola* (Greef) Mull. O. 2.

CEREAL DISEASES.

WHEAT.

Downy Mildew. *Sclerospora macrospora* Sacc. Carne, 1924 (b). R. 3. W. Recorded from wet places at Three Springs, 1923, Nembudding and Bruce Rock, 1924.

Mildew. *Erysiphe graminis* DC. O. 1-2. W. Sutton, 1920 (a). See Carne and Campbell, 1924 (b).

Black Mould. *Mycosphaerella tulasnei* Jacz and *Alternaria* sp. C. 1-2. W. When crops are ripening off, especially in moister districts, e.g., Victoria district. Carne and Campbell, 1924 (b).

Take-all. *Ophiobolus cariceti* (Berk and Br.) Sacc. O-C. 3-4. W. Sutton, 1920 (a). See Carne and Campbell, 1924 (a).

Loose Smut. *Ustilago tritici* (Pers) Rost. O-C. 2. W. Sutton, 1920 (b).

Ball Smut or Bunt. *Tilletia levis* Kuehn. VC. 3-4. W. See Carne, 1925 (a).

Ball Smut or Bunt. *Tilletia tritici* (Bjerk) Wint. Recorded by McAlpine, 1910. Apparently rare. See Carne, 1925 (a).

Flag Smut. *Urocystis tritici* Koern. O. 3. W. Carne 1924 (a). Confined at present to the Eastern Wheat Belt. See also Carne, Smut Diseases, 1925.

Stem Rust. *Puccinia graminis* Pers var. *tritici.* Carne and Campbell, 1924 (c). R. 4. W. Found in unimportant amounts in Northampton-Geraldton-Midland areas most years, and to a lesser extent in the Eastern Wheat Belt. Rarely epidemic. The last year of serious occurrence was in 1917. That year was characterised in the area affected by exceptionally heavy rainfall in July, August, September and October. These months were exceptionally cloudy and dull and much below the average in temperature. In October the rains ceased, and were followed by warm days and fogs. Mr. W. Waterhouse, of Sydney University

has examined rust specimens from this district, and states that all belong to his Biologic Form. 1.* Recorded by Helms, 1900.

Leaf Rust. *Puccinia triticina* Eriks. Recorded by McAlpine, 1906. Not seen by author.

Take-all (associated with *Wojnowicia graminis* (McAlp.) Sacc and D. Sacc.) Seen only from Quairading, February, 1924, associated with *Ophiobolus cariceti.*

Leaf Spot. *Septoria gramineum* Desm. VC. 1. W. Carne and Campbell, 1924 (b).

Dry Blight or Septoria. *Septoria nodorum* Berk. O. 2-3. W. Carne and Campbell, 1924 (b).

Ear-Cockle. *Tylenchus tritici* (Stein) Vast. O. 3. W. Helms, 1898.

Whiteheads. O. 4. W. Due to too early planting or unfavourable conditions, such as salt soils, drought, frost, or dry winds at flowering time. Carne and Campbell, 1924 (a).

BARLEY.

Mildew. *Erysiphe graminis* D.C. O. 1-2. W. Carne and Campbell, 1924 (b).

Naked Smut. *Ustilago nuda* (Jens) K & S. O. 1-2. W. Sutton, 1920 (b).

Covered Smut. *Ustilago hordei* (Pers) K & S. O. 1-2. W. Sutton, 1920 (b).

Leaf Spot. *Septoria (? passerinii* Sacc). O. 1. W. Carne and Campbell, 1924 (b).

Leaf Stripe. *Helminthosporium gramineum* (Rab) Erik. VC. 1-2. W. Carne and Campbell, 1924 (b).

Black Mould. *Mycosphaerella tulasnei* Jacz. OC. 1-2. W. On maturing crops in moister districts. Carne and Campbell, 1924 (b).

OATS AND BLACK OATS (Avena fatua).

Mildew. *Erysiphe graminis* DC. O. 1. W. Carne and Campbell, 1924 (b).

Black Mould. *Mycosphaerella tulasnei* Jacz. OC. 1-2. W. Common in moister districts. Carne and Campbell, 1924 (b).

* From an unpublished paper, "Notes on Rust Investigations in Progress," W. L. Waterhouse, B.Sc. Agr., read before Pan Pacific Conference at Sydney, 1923.

Leaf Spot. *Leptosphaeria avenaria* Weber. O. 1. W. Carne and Campbell, 1924 (b).

Covered Smut. *Ustilago levis* (K & S) Magn. VC. 2. W. Not seen on Black Oats.

Loose Smut. *Ustilago avenae* (Pers) Jens. O. 2 W. McAlpine, 1910.

Stem Rust. *Puccinia graminis* Pers var. *avenae*. O. 2. W. Carne and Campbell, 1924 (c).

Leaf Rust. *Puccinia coronata* Cda. O-C. 2. W. Common in moister districts. Carne and Campbell, 1924 (c).

RYE.

Stem Rust. *Puccinia graminis.* R. —. W. Recorded only from Merredin, 1924.

MISCELLANEOUS ECONOMIC PLANTS.

LUCERNE.

Leaf Spot. *Pseudopeziza medicaginis* (Lib) Sacc. VC. 2. D.

Rust. *Uromyces medicaginis* Pass. O. 2. D.

TOBACCO.

Eelworm. *Heterodera radicicola* (Greef) Mull.

MISCELLANEOUS EXOTIC PLANTS (NOT CROP PLANTS).

CARNATION.

Rust. *Uromyces caryophyllinus* (Schw.) Wint. O. 3. W.

Leaf Spot. *Septoria dianthi* Desm. Maylands, 1924.

Leaf Mould. *Heterosporium echinulatum* (Berk) Cke. Belmont, 1924.

CHRYSANTHEMUM.

Mildew. *Erysiphe cichoracearum* DC. O. 3. W.

Malformation of Flowers. Non-parasitic. Due to nutrition troubles of forced plants.

GERANIUM (Pelargonium zonale).

Rust. *Puccinia Morrisoni* McAlp. O-VC. 2-3. W & D. Very common around Perth and near coast.

GRASSES.

Avena fatua L. See under Oats.

Bromus maximus L. Perth, 1923 and 1924.
Rust. *Puccinia bromina* Eriks.

Bromus unioloides. H. Br. K. Manjimup, etc., in sown pastures, 1924.

Bromus mollis L. Mt. Barker, 1924.
Smut. *Ustilago bromivora* (Tul.) F.v.W.

Cynodon dactylon Rich.
Smut. *Ustilago cynodontis* P. Henn. Common around Perth.

Holcus lanatus L.
Rust. *Puccinia coronata* Cda. Common in coastal districts from Perth southward.

Hordeum murinum L.
Stripe Disease. *Helminthosporium gramineum* Erik (Rab). Carne and Campbell, 1924 (b).

Panicum crusgalli L.
Smut. *Cintractia crus-galli.* Mag. Wanneroo, 1922.

Poa annua L.
Rust. *Puccinia poarum* Niels R. Around Perth.

Grass Lawns.
Physarum cinereum (Batch) Pers. A saprophyte. O. W. On lawns of Stenotaphrum dimidiatum and Cynodon dactylon around Perth.

Lysurus gardneri Berk. A saprophyte. O. W. Autumn, especially on Stenotaphrum dimidatum lawns. Herbert, 1919-20.

Hollyhock.
Rust. *Puccinia malvacearum* Mont. VC. W & D. Common around Perth.

Lavatera trimestris L.
Rust. *Puccinia malvacearum* Mont. South Perth. 1924.

Malva parviflora L.
Rust. *Puccinia malvacearum* Mont. VC. W & D. Does not appear to exercise any control over this weed. Common around Perth.

Phlox Perennial.
Septoria sp. Perth, 1924.

Rose.
Mildew. *Sphaerotheca pannosa* (Wallr.) Lev. VC. 3-4. W. & D.

Black Spot. *Actinonema rosae* (Lib.) Fr. O. 2-3. W & D.

Shepherds Purse. (*Capsella bursa-pastoris*).
White Rust. *Albugo candida* (Pers.) Rouss. O. W.

Sunflower.
Rust. *Puccinia helianthii* Schw. C. D. Perth. Herbert. 1920-21. Common around Perth.

Trefoil (*Medicago denticulata*).
Leaf Spot. *Pseudopeziza medicaginis* (Lib.) Sacc. W. (spring). Bickley, 1923.

NATIVE PLANTS.

Acacia acuminata. Benth. Wongan Hills, 1924, and Muresk, 1925.

A. cyclopis. A. Cunn. Swan River, 1924.

A. cyanophylla. Lindl. Gingin and Kelmscott, 1924.

A. erioclada. Benth. McAlpine, 1906.

A. glauceptera. Benth. McAlpine, 1906.

A. ligustrina. Meissn. Wongan Hills, 1924.
Gall Rust. *Uromycladium Tepperianum* (Sacc) McAlp.

Acacia extensa. Lindl. Cheel, 1911.
Gall Rust. *Uromycladium* sp.

Acacia spp.
Armillaria mellea (Vahl) Quel. Collie, 1924.

Arundo sp.
Coniosporum inquinans Dur and Mont. McAlpine, 1895.

Boronia juncea Bart.
Sphaeropsis boroniae P. Henn. Perth. Hennings, 1901.

Boronia spinescens Benth.
Puccinia boroniae P. Henn. Avon. Hennings, 1903.

Bossiaea linophylla, R. Br.
Aecidium eburneum McAlpine. King George's Sound. McAlpine, 1906.

Bromus arenarius Labill.
Ustilago bromivora Wall. Tammin, Cheel, 1910.
Puccinia bromivora Eriks. Wongan Hills, 1904.

Burchardia umbellata R. Br.
Puccinia Burchardiae Sacc. Perth, 1915.

Conostylis aurea Link.
Puccinia haemodori P. Henn. Perth. Cheel, 1909.

Dampiera leptoclada Benth. Albany. Cheel, 1909.

D. spicigera Benth. Murchison R. Cheel, 1909.

D. alata Lindl. Perth. McAlpine, 1906.
Puccinia dampierae Syd.

Eucalyptus diversicolor F & M.
Xylostroma gigantea Fries. Big Brook. Herbert, 1919-20.

Eucalyptus spp, especially E. calophylla R. Br. Common.
Armillaria mellea (Vahl) Quel. Bibra Lake, etc., 1923, but apparently does not affect trees.

Gastrolobium spinosum Benth.
Lizonia oxylobii P. Henn. Perth. Hennings, 1901.

Grevillea sp.
Phyllachora grevilleae Sacc. McAlpine, 1895.

Haemodorum sp.
Puccinia haemodori P. Henn. Perth. Hennings, 1901.

Hakea glabella R. Br. Herbert, 1919-20.

Hakea sp. Thuemen, 1878.
Uredo angiosperma Thuem.

Jacksonia macrocalyx Meissn.
Pestalozzia jacksoniae P. Henn. Perth. Hennings, 1901.

Jacksonia sternbergiana Heug.
Cronartium jacksoniae P. Henn. Perth. Cheel, 1910.

Juncus pallidus R. Br.
Tolysporium juncophilum McAlpine. Mt. Barker. McAlpine, 1900.

Leucopogon hispidus Pritzel.
Lizonia singularis P. Henn. Mingenew. Hennings, 1903.

Leschenaultia linarioides DC.
Puccinia gilgiana P. Henn. (including *Aecidium Perkensiae* P. Henn). Perth. Hennings, 1901.

Oxylobium lineare Benth.
Lizonia oxylobii P. Henn. Perth. Hennings, 1901.

Pelargonium australe Wield.
Puccinia Morrisoni McAlpine. Cowcowing. Cheel, 1909.

Persoonia elliptica R. Br.
Hendersonia persooniae P. Henn. Perth. Hennings, 1901.

Piperomia sp.
Eurotium lateritium Mont. McAlpine, 1895.

Synaphea polymorpha R. Br.
Dimerosproium synapheae P. Henn. Perth. Hennings, 1901.

Threlkeldia drupata Diels.
Puccinia Dielsiana P. Henn. Perth. Hennings, 1901.

Tremandra stelligera R. Br.
Puccinia Pritzeliana P. Henn. Perth. Hennings, 1901.

Xylomelum occidentalis R. Br.
Physalospora xylomeli P. Henn. Perth. Hennings, 1901.

PHANEROGAMIC PARASITES.

Cuscuta epithymum L.—O. 3. W. Recorded only on Trifolium subterraneum.

Loranthus spp.— Various species and their hosts are recorded by W. F. Blakeley in Proceedings of Linnean Society of N.S.W., commencing Vol. XLVII., 1922, and still being published.

Nuytsia floribunda R. Br.— On roots of citrus, broad beans, carrot, rose, grape, Cytisus proliferus, Rumex acetosella, Cynodon dactylon, Pelargonium zonale, Solanum nigrum var., Hibbertia hypericoides, Banksia attenuata, B. Menziesii, Simsia latifolia, Melaleuca Huegelii, M. viminea, Conostephium pendulum, Jacksonia furcellata, Calythrix flavescens, Acacia pulchella. D. A. Herbert, Pro. Royal Soc. W.A., V. 1918-19, p. 72. On roots of Casuarina humilis. Unpublished record by C. A. Gardner. On roots of Pinus radiata. Ludlow, 1925.

Fusanus spicatus R. Br.— On roots of Acacia acuminata, A. aneura, A. craspedocarpa, A. doratoxylon, A. microbotrya, A. Oswaldi, A. signata, Cassia eremophila, C. artemisioides, Templetonia retusa, Casuarina campestris, C. Huegeliana, Dodonaea attenuata, D. attenuata var. linearis, D. filifolia, D. inaequifolia, D. lobulata, Eremophila Goodwinii, E. Oldfieldii, E. Dempsteri, E. Paisleyi, E. oppositifolia, E. scoparia, Hakea commutata, H. recurva, Melaleuca uncinata, Kochia sp. D. A. Herbert and C. A. Gardner. Proc. Roy. Soc. W.A., 1920, p. 77, and unpublished records by C. A. Gardner.

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List of the Naturalised Plants of Extra-Tropical Western Australia.

By **C. A. Gardner,** Department of Agriculture, Perth.

(*Read* March 10, 1925. *Published* June 27, 1925).

The following list of plants has been compiled from various sources, and, together with a few species not previously recorded, represents those species of plants which, originally natives of other countries, have been introduced and become naturalised here. The greater number of these species are well known either as plants of fodder value, or as weeds, while a few are apparently scarce, or are establishing themselves, and at the present time are only known from a few localities.

Apart from the very incomplete list drawn up by W. B. Alexander, C. E. Lane-Poole, and D. A. Herbert in Vol. VI. of this Society's Journal, no list of the naturalised plants of this State has been published, and it is hoped that this list will serve as a basis for any future work that might be attempted.

In compiling this paper, only that portion of the State which lies to the south of the 26th parallel of latitude (Shark's Bay) has been included. There are, therefore, some species omitted which are naturalised in the area to the north of this line, and some which are indigenous there are included as naturalised plants in the southern area.

As referred to in this paper, the "South-West" does not refer to the political South-West Division, but for convenience is a name that has been applied for the purpose of this paper, to that portion of the State bounded on the north by the Eastern Railway, and on the east by the Great Southern Railway. This, of course, is not a biological boundary, but one adopted for convenience.

The number of species now recorded as naturalised in extra-tropical Western Australia is 237. Of this number 48 originally come from the Mediterranean region, 34 are from South Africa, 11 from North America, and 7 from South America. Three are from other parts of Australia. The greater portion of the remaining species are of European or Asiatic origin, and a few are cosmopolitan. Most of the Gramineae are of European origin, while the greater number of the Compositae belong to the Mediterranean region.

The following species, although included in the previous list referred to above, have, for what are considered good reasons, been omitted from this paper:—

Cuscuta europaea, Œnothera odorata, Olea europaea, Lolium perenne, Medicago sativa, Trifolium medium, T. pratense, Onopordon acanthum, and Xanthium strumarium.

I desire to acknowledge my indebtedness to Mr. W. M. Carne, Botanist and Plant Pathologist to the Department of Agriculture, for his assistance, which has greatly facilitated this work.

MONOCOTYLEDONEAE.

Gramineae.

Andropogon halepensis, (L.) Sibth.	Johnson Grass	Mediterranean
Tragus racemosus, (L.) Haller	Small Burr-grass	Medit. & Afghan.
Paspalum dilatatum, Poir	Paspalum	Brazil
Paspalum distichum, Linn.	Water-Couch	Trop. and Sub-trop. Reg.
Echinochloa colona, (L.) Linn. (Panicum colonum, L.)	——	Cosmopolitan
Echinochloa Crus-Galli, (L.) Beauv. (Panicum Crus-Galli, L.)	Barnyard Grass	Cosmopolitan
Digitaria marginata, Linn. (Panicum sanguinale, L.)	Crab-Grass	Cosmopolitan
A common summer-grass in the Metropolitan area, and a weed in gardens and orchards.		
Digitaria sanguinalis, (L.) Scop. (Panicum sanguinale, L.)	Ditto.	
Cenchrus pauciflorus, Benth.	Burr-grass	N. America
Pennisetum villosum, R.Br.	——	Abyssn.
Ehrharta brevifolia, Schrad.	Veldt Grass	S. Africa
Ehrharta brevifolia, Schrad. var. cuspidata, Nees.	Veldt Grass	S. Africa
Common winter grass in the South-West, introduced in early days.		
Ehrharta calycina	Veldt Grass	S. Africa
Ehrharta longiflora	Veldt Grass	S. Africa
Common on the western coastal plain, particularly in Metropolitan area.		
*Phalaris canariensis, Linn.	Canary Grass	E. & N. Africa
Phalaris minor, Retz.	Canary Grass	Europe, Asia and Africa
Anthoxanthum odoratum, Linn.	Scented Vernal Grass	Europe, Asia and N. Africa
Oryzopsis miliacea, (L.) Aschers et Sch.	Many-flowered Millet.	Medit. Reg.

Polypogon monspeliensis, Desf.	Beard-Grass	Almost Cosmop.
Agrostis alba, Linn.	Creeping Bent-grass	Europe & Asia
Confined to South-West.		
Agrostis verticillata, Vill.	——	Europe
Confined to South-West.		
Lagurus ovatus, L.	Hare's-tail-grass Scarce.	Europe and N. Africa
Aira capillaris, Host.	——	Europe & Asia
Aira caryophyllea, Linn.	Silvery Hairgrass	Europe & Asia
*Aira minuta, L.	——	Europe & Asia
Aira pracox, L.	——	Europe & Asia
Avena barbata, Brotero.	Yatheroo-Oat	Medit., As. Minor & Arabia
Avena fatua, Linn.	Black, or Wild Oat	Europe & N. Asia
Widely distributed.		
Avena sterilis, L.	Oat	Medit. & Asia
Arrhenatherum avenaceum (L.) Beauv.	Tall Oat Grass	Europe & Asia
Only recorded from Denmark.		
Holcus lanatus, Linn.	Yorkshire Fog	Europe
Confined to South-West, in moister soils.		
Pentaschistis Thunbergii (Kunth) Stapf.	——	South Africa
Only known from Guildford district.		
Koeleria phleoides, Pers.	——	Mediterranean
Briza maxima, Linn.	Blowfly, or Large Quaking Grass	Mediterranean
A common and widely distributed species.		
Briza minor, Linn.	Lesser Quaking Grass	Europe
Common and widely distributed.		
*Dactylis glomerata, Linn.	Cocksfoot Grass	Europe & Asia
Poa annua, Linn.	Goose-grass	Cosmopolitan
Common.		
Poa bulbosa, Linn.	——	Europe
Festuca bromoides, Linn.	Silver-grass	Temperate Reg.
Festuca elatior, Linn.	——	Europe
Festuca Myuros, Linn.	Silver-grass	Almost Cosmop.
A very common species, with wide range.		
Festuca rigida, (L.) Kunth.	——	Europe & Asia
Bromus madritensis, Linn.	Madrid Brome	Mediterranean
Fairly common.		
Bromus maximus, Desf.	Great Brome, or Spear-grass	Europe
Bromus mollis, Linn.	Soft Brome	Europe
A common species in the South-West.		

Bromus sterilis	Sterile Brome	Europe & W. Asia

Not very common.

Cynodon dactylon, Pers.	Couch-grass	Cosmopolitan

Native to the North, naturalised in moister parts of South-West.

Brachypodium distachyum, R. et S.	——	Mediterranean

Only recorded from Walebing.

*Chloris gayana	Rhodes-grass	Tropical Africa
Lolium multiflorum, Lam.	Italian Rye Grass	France
Lolium subulatum, Vis.	Wimmera Rye Grass	Sth. Europe
Lolium temulentum, Linn.	Drake, or Darnel.	Europe & Asia

Common in cultivations.

Lepturus incurvatus, Trin.	Curly Hard-grass.	Europe
Hordeum murinum, Linn.	Barley-grass.	Cosmopolitan

A very common species.

In addition to the above grasses, Wheat, Oats, Barley and Rye are naturalised in places.

Cyperaceae.

*Cyperus rotundus, Linn.	Java-grass or Nut-grass	Cosmopolitan

Araceae.

Richardia africana, Kunth.	Arum Lily	S. Africa

Now naturalised in swampy spots of the South-West.

Pontederiaceae.

Eichhornia crassipes, Solms.	Water-hyacinth.	Tropical America

In fresh-water lakes and creeks, in the Metropolitan area.

Juncaceae.

†Juncus bufonius, Linn.	Toad-rush.	Cosmopolitan
Juncus capitatus, Weig.	Capitate Rush.	Cosmopolitan

Liliaceae.

Asphodelus fistulosus, Linn.	Onion-weed	Medit. Reg.

Common in the Metropolitan Area.

†Bulbinella caudata, Kunth.	——	South Africa
Allium triquetrum, Linn.	——	Europe & N. Africa

Recorded from Perth, apparently naturalised.

Amaryllidaceae.

†Zephyranthes atamasco, Herb.		America

Iridaceae.

Watsonia angusta, Ker.	"Watsonia"	S. Africa

Escaped from Gardens, and now naturalised in the South-West.

Romulea rosea, (L.) Eckl.	Guildford Grass	S. Africa
Common in the South-West.		
Homeria collina (Thunb.) Vent.	Cape-Tulip	S. Africa
Common in the York and Northam districts.		
Homeria miniata, Sweet.	Cape-Tulip	S. Africa
Babiana plicata (Thunb.) Ker.	——	S. Africa
Ferraria undulata, Linn.	——	S. Africa
†Hesperantha falcata, Ker.	——	S. Africa
Freesia refracta	Freesia	S. Africa

DICOTYLEDONEAE.

Urticaceae.

Urtica urens, Linn.	Nettle	Temperate Reg.
Not common.		

Polygonaceae.

Rumex aceosella, Linn.	Sheep Sorrel.	Europe & Asia
Common in South-West.		
*Rumex conglomeratus, Murray	Clustered Dock	Europe & Asia
*Rumex crispus, Linn.	Curled Dock	Europe & Asia
*Rumex pulcher, Linn.	Fiddle Dock	Europe & Asia
Emex australis, Stein.	Double-Gee	S. Africa
Common.		
Polygonum aviculare, Linn.	Wire-weed	Cosmopolitan
Widely distributed and common.		

Chenopodiaceae.

Chenopodium album, Linn.	Fathen	Almost Cosmop.
A cultivated variety known as "Mexican Spinach" also appears to have escaped from cultivation.		
Chenopodium ambrosioides, L.	Mexican Tea	Trop. & Temp. Reg.
†Chenopodium glaucum, Linn.		Europe & Asia
*Chenopodium murale, Linn.	Nettle-leaved Fathen	Cosmopolitan
†Chenopodium olidum, S. Wats.	——	N.S.W. & Qld. (Aust.)

Amarantaceae.

†Amarantus paniculatus, Linn.	Red Leg	North America
Amarantus retroflexus, Linn.	——	North America

Phytolaccaceae.

Phytolacca octandra, L.	Red-Ink Plant	Japan

Aizoaceae.

Mesembrianthemum crystallinum, L.	Ice-plant	Europe, Calif. & S. Africa
Fairly common.		

†Mesembrianthemum edule, L.	Hottentot Fig	South Africa
Mesembrianthemum tumidulum, Haw.	——	South Africa

Recorded from the Albany district.

Portulacaceae.

Portulaca oleracea, Linn.	Purslane.	Native to the warmer parts of Australia

Naturalised in S.W. Australia.

Caryophyllaceae.

Silene gallica, Linn.	Catchfly.	Europe & Asia
Common in South-West.		
Tunica prolifera (L.) Scop.	Wild Carnation.	Europe
Common in cultivations.		
Saponaria Vaccaria, Linn.	Soapwort	Europe
Not very Common.		
Cerastium glomeratum, Thuill.	Chickweed	Temp. & Sub-trop. Reg.
Sagina apetala, Arduino.	——	Europe
Spergula arvensis, Linn.	Corn Spurry	Europe
Spergularia Bocconei (Soleirol) Steud.	——	Europe
Spergularia campestris, (L.) Aschers.	Sand Spurry	Europe
Polycarpon tetraphyllum, Loef.	——	Europe
Stellaria media, (L.) Vill	Chickweed	Europe
Very common.		

Ranunculaceae.

Ranunculus muricatus, Linn.	"Buttercup"	Europe
Rare.		

Papaveraceae.

Argemone mexicana, Linn.	Mexican Poppy	N. America
Fumaria muralis, Sond.	Fumitory	Europe & temp. Asia

Common in the moister parts of the South-West.

Cruciferae.

Diplotaxis muralis, (L.) A.D.C.	Sand Rocket	Europe
Roripa Nasturtium-aquaticum, Hayek.	Watercress	North temp. Reg
In streams in the South-West.		
*Barbarea praecox, R.Br.	Early Winter Cress	West Europe
Barbarea vulgaris, R.Br.	——	Europe & temp. Asia

Sisymbrium officinale, Linn.	Hedge Mustard	Europe & W. Asia
Sisymbrium orientale, Linn.	Wild Mustard	Europe
	Common.	
Brassica Sinapistrum, Boiss	Charlock, or Wild Mustard	Europe & W. Asia
Capsella Bursa-pastoris, (L.) Moench.	Shepherd's Purse	Temperate Reg.
	Very common, and widely distributed.	
Lepidium Draba, Linn.	Hoary Cress	Europe
Coronopus didymus, (L.) Sm.	Swine Cress	Cosmopolitan
	Common in the South-West.	
Heliophila pusilla, Linn.	——	S. Africa
	In the Metropolitan Area.	
Cakile maritima, Scop.	Sea Rocket	Europe & Asia
	Common on the sea coast.	
Raphanus Raphanistrum	Wild Radish	Temperate Reg.
	Very common in cultivations.	

Resedaceae.

Reseda luteola, Linn.	Wild Mignonette	Europe & Asia

Rosaceae.

Rubus fruticosus, L.	Blackberry	Europe
	Fairly common in shady valleys in South-West.	
Rosa rubiginosa, Linn.	Sweetbriar	Europe & Asia Minor

Leguminosae.

Ulex europaeus, Linn.	**Furze**	West Europe
	Naturalised in the Albany district.	
Psoralea pinnata, Linn.	Taylorina	S. Africa
	Naturalised in the Albany district.	
Medicago denticulata, Willd.	Burr Trefoil	Europe
	Fairly common, and widely distributed.	
Medicago lupulina, Linn.	English Trefoil	Europe, Asia & North Africa
Medicago arabica, (L.) All.	Spotted Trefoil	Europe & W. Asia
Melilotus alba, Desr.	Bokhara Clover	Europe & W. Asia
	Apparently rare.	
Melilotus indica, All.	King Island Melilot	Europe & W. Asia
Trifolium angustifolium, L.	Narrow-leaved Clover	Mediterranean
Trifolium arvense, L.	Hare's-foot Clover	Europe & W. Asia
Trifolium cernuum, Brot.	Drooping-flowered Clover	Portugal
Trifolium dubium, Sibth.	Yellow Suckling Clover	Europe
	Common, and widely distributed in South-West.	

Trifolium fragiferum, Linn.	Strawberry Clover	Europe
	Rare.	
Trifolium glomeratum, L.	Clustered Clover	Europe & Asia
Fairly common in South West.		
Trifolium incarnatum, L.	Crimson Clover	Europe
	Rare.	
Trifolium lappaceum, Linn.	Star Clover.	Asia Minor
Only recorded from Moore River.		
Trifolium procumbens, L.	Hop Clover	Europe & W. Asia
A common species, widely distributed.		
Trifolium repens, L.	White, or Dutch Clover	Europe & Russian As.
Trifolium resupinatum, Linn.	Shaftal Clover	Mediterranean
*Trifolium striatum, L.	Knotted Clover	West Asia
Trifolium subterraneum, L.	Subterranean Clover	Europe
Trifolium tomentosum, Linn.	Woolly Clover	Medit. Reg
Lotus angustissimus, Linn.	Manjimup Clover	Europe & Asia
Lotus hispidus, Desf.	Boyd's Clover	Europe & N. Africa
Vicia gemella, Crantz.	Slender Vetch	Europe & Asia
Vicia hirsuta, (L.) S. F. Gray	Hairy Vetch	Medit. Reg.
Vicia sativa, Linn.	Vetch	Europe & N. Africa
Lupinus hirsutus, Linn.	Blue Lupin	Mediterranean
Acacia pycnantha, Benth.	S. Australian Golden Wattle	S. Aust. & Vic.
Recorded from the Mundaring district.		

Geraniaceae.

Geranium molle, Linn.	Wild Geranium	Europe & W. Asia
Erodium cicutarium, (L.) L'Herit.	Crowfoot	Cosmopolitan
Very common, distributed throughout the southern part of the State.		
Erodium moschatum, (L.) L'Herit.	Crowfoot	Europe & W. Asia
*Pelargonium graveolens, (Thunb.) L'Herit.	Rose Geranium	S. Africa

Oxalidaceae.

Oxalis cernua, Thunb.	Soursob	S. Africa
Oxalis polyphylla, Jacq.	——	S. Africa
	Rare.	
Oxalis variabilis, Jacq.	——	S. Africa
	Rare.	

Linaceae.

Linum flavum, Linn.	Yellow Flax	Europe & Asia Minor
Fairly common in the Blackwood district.		
*Linum gallicum, Linn.	Flax	Medit. & Abyssn.

Zygophyllaceae.

Tribulus terrestris, Linn.	Caltrop	Mediterranean

Euphorbiaceae.

Euphorbia dendroides, Linn.	——	Medit. coasts
Euphorbia peplus, Linn.	Milkweed	Europe & Asia
Euphorbia terracina, Linn.	Geraldton Carnation Weed	Mediterranean
Ricinus communis, Linn.	Castor-oil Plant	Africa (?)
Eremocarpus setigerus, Benth.	Dove-weed	California

Only recorded from the Moora district.

Malvaceae.

Lavatera trimestris, Linn.	——	Medit. Reg.

Only recorded from the Bunbury district.

Malva parviflora, Linn.	Small-flowered Mallow	Mediterranean
*Malva rotundifolia, Linn.	Marsh Mallow	Europe & N. Asia
Modiola caroliniana, (L.) G. Don.	——	S. America

Cactaceae.

Opuntia monocantha, Haw.	Prickly-Pear	S. America

Onagraceae.

Œnothera biennis, Linn.	Evening Primrose	N. America

Umbelliferae.

Bupleurum protractum, Link et Hoffm.	——	East Medit. Reg.

Recorded from Katanning and Gnowangerup.

Foeniculum vulgare, Mill.	Fennel	Europe & Asia
Ammi majus, Linn.	——	Europe, Asia & N. Africa
Petroselinum sativum, Hoffm.	——	Europe & Medit. Reg.

Primulaceae.

Anagallis arvensis, Linn.	Red Pimpernel	Europe & temp. Asia

Widely distributed.

Anagallis foemina, Mill.	Blue Pimpernel	Europe & temp. Asia

Very common.

Gentianaceae.

*Centaurium Erythraea, Rafn.	"Centaury"	Europe

Ascelepiadaceae.

Gomphocarpus fruticosus, R.Br.	Wild Cotton	Medit. Reg.

Convolvulaceae.

Convolvulus arvensis, Linn.	Bindweed	Europe
Cuscuta Epithymum, Linn.	Dodder	Europe & N. Asia

Hydrophyllaceae.

Wigandia urens, H.B. & K.	——	Mexico
Found in the Metropolitan Area, escaped from gardens, and now naturalised.		

Boraginaceae.

Echium plantagineum, Linn.	Patterson's Curse	Medit. Reg.
Very common in many places.		
Lithospermum arvense, Linn.	Whiteweed	Europe
Established in some places.		

Labiatae.

Rosmarinus officinalis, Linn.	Rosemary	Medit. Reg.
Naturalised around New Norcia.		
Marrubium vulgare, Linn.	Horehound	Europe, Asia & N. Africa
Salvia verbenaca, Linn.	Wild Sage	Europe & Asia
Stachys arvensis, Linn.	Stagger-weed	North temp. Reg.
Very common in the Metropolitan Area.		
Moluccella laevis, Linn.	"Shell Plant"	Western Asia
Naturalised around Bremer Bay, where it is said to be common, and recorded also from Gnowangerup.		
Leonotis Leonurus, R.Br.	Lion's Ear	S. Africa
Naturalised at Fremantle.		
*Mentha Pulegium, Linn.	Pennyroyal	Europe, Asia & N. Africa

Solanaceae.

Solanum aculeatissimum, Jacq.	Devil's Apple	S. America
Recorded from Bayswater.		
Solanum nigrum, Linn. var.	——	Cosmopolitan
Solanum rostratum, Dun.	Buffalo Burr	Mexico
Solanum sodomaeum, Linn.	Apple of Sodom	Medit. & S. Africa
Common in the littoral tracts.		
Datura stramonium, Linn.	Thorn Apple	Trop. & Sub-trop. Regions
†Datura Tatula, Linn.	Purple-flowered Thorn Apple	Trop. & Sub-trop. Regions
Nicotiana glauca, R. Grah.	Tree Tobacco	Argentine
Lycium ferocissimum, Miers.	Boxthorn	
Widely distributed, but not common.		

Scrophulariaceae.

Verbascum virgatum, Stokes.	Twiggy Mullein	Europe
*Linaria Elatine, Mill.	Pointed Toadflax	Europe & Asia
Limosella aquatica, Linn.	——	Temperate Reg.
Recorded from Armadale.		
Parentucellia latifolia, (L.) Caruel	Bartsia	Medit. & S.W. Asia
A common species to the South-West.		
Parentucellia viscosa (L.) Caruel.	Bartsia	Medit. Reg.
Recorded from various stations of the West coastal plain.		
Bellardia Trixago, All. (Bartsia Trixago, Kun.)	——	Europe & S. Africa
Dischisma arenarium, E. Mey.	——	S. Africa
Recorded from Margaret River district.		
Dischisma capitatum, (Thunb.) Choisy	——	S. Africa
Common in the Swan River district.		

Orobanchaceae.

Orobanche cernua, Loefl.	Broom Rape	Almost Cosmop.
Common in the Metropolitan district.		

Plantaginaceae.

Plantago lanceolata, Linn.	Rib-grass	Europe, Asia & N. America
†Plantago major, Linn.	Rib-grass	Europe & N. Asia

Cucurbitaceae.

Cucumis myriocarpus, Naudin.	Wild Melon	S. Africa
Common in the Eastern districts.		

Campanulaceae.

Wahlenbergia capensis, A.D.C.	Cape Bluebell	S. Africa
A recent introduction into the Metropolitan area.		
Monopsis debilis, (Linn. f.) Presl.	——	S. Africa
Fairly common in the moister soils of the Metropolitan and Midlands districts.		

Compositae.

Centaurea calcitrapa, Linn.	Purple Cockspur	Europe
Centaurea melitensis, Linn.	Yellow Cockspur	Europe & S. America
*Centaurea solstitialis, Linn.	Yellow Cockspur	Europe
Cynara Scolymus, Linn.	Artichoke	Medit. Reg.

*Silybum marianum, Gaertn.	Spotted Thistle	Europe, N. Africa & Asia
Carduus lanceolatus, Linn.	Spear Thistle	Europe
Carduus pycnocephalus, L.	Slender Thistle	West & South Europe
Kentrophyllum lanatum, A.D.C.	Star Thistle	Mediterranean
Erigeron canadensis, Linn.	——	N. America
Recorded from York.		
Erigeron linifolius, Willd.	——	Mediterranean
Inula graveolens, Desf.	Stinkwort	Mediterranean
Xanthium spinosum, Linn.	Bathurst Burr	Cosmopolitan
Widely distributed, but not very common.		
†Galinsoga parviflora, Cav.	——	S. America
Ursinia anthemoides, Gaertn.	——	S. Africa
A common weed of the Metropolitan Area.		
Cotula bipinnata, Thunb.	——	S. Africa
Senecio vulgaris, Linn.	Groundsel	Europe
Cryptostemma calendulaceum, R.Br.	Cape-weed	S. Africa
A second species of this genus has made its appearance during recent years near Kalgoorlie.		
Tripteris clandestina, Less.	Stinking Roger	S. Africa
Widely distributed and common.		
Cichorium Intybus, Linn.	Chicory	Europe & Asia
Arnoseris minima, Dum.	——	Europe
Hypochoeris radicata, Linn.	Flatweed-Dandelion	Europe & N. Africa
Very common.		
*Sonchus asper, Hill.	Rough Milk-thistle	Cosmopolitan
Sonchus oleraceus, Linn.	Common Milk-thistle	Cosmopolitan
Common weed.		
*Taraxacum officinale, Weber.	Common Dandelion	Europe & Asia
Lactuca saligna, Linn.	Prickly Lettuce	Asia & N. Africa
Lactuca scariola, Linn.	Prickly Lettuce	Europe & W. Asia

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* Not seen by Author. Recorded by D. A. Herbert, Journ. Roy. Soc. W.A., vi. (part i.).

† Not seen by Author. Recorded by R. Helms, Journal of Agriculture, W.A., Series I.

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A New Blind Freshwater Amphipod (genus Neoniphargus from Western Australia, by **Chas. Chilton,** M.A., D.Sc., M.B., C.M., LL.B., Rector and Professor of Biology, Canterbury College, N.Z.

Communicated by L. Glauert.

(*Read* March 10, 1925. *Published* July 1, 1925).

Towards the end of 1923 I received a letter from Mr. L. Glauert, of the Perth Public Museum, forwarding specimens of a blind fresh water gammarid from the Darling Ranges (Darlington). He stated that a few specimens had been forwarded to Dr. W. T. Calman, of the British Museum about a year previously. On preliminary examination the Amphipod appeared to be a new species of the genus *Neoniphargus,* and I got into correspondence with Dr. Calman, of the British Museum, about a year previously. On pretime to describe the species, but had made a drawing of the whole animal. This he sent on to me with the request that I would complete the description, and this I accordingly do in the present paper.

The species proves to belong undoubtedly to *Neoniphargus,* though in one or two respects it differs somewhat markedly from species hitherto described. This is shown mainly in the sexual characters, which are very distinct. Thus in the male the second antenna is particularly short and stout, and there is also a distinct difference between the two sexes in the third uropoda.

From the description given below, and also from that of other species of the genus described in more recent years, it will be seen that the generic diagnosis given by Stebbing in 1906 (p. 404) requires modification in several particulars. Thus the eyes are wanting in the present species, the accessory flagellum is more than two-jointed, the two pairs of gnathopoda are hardly similar, and the third uropod has the outer branch distinctly two-jointed. But the resemblances to the species *N. fultoni* and *N. spenceri,* described by the late O. A. Sayce, and to *N. branchialis* recently described by Professor G. E. Nicholls (1924, p. 105) are so numerous that it is desirable to widen the genus to include them all.

In *N. branchialis* Nicholls, which has been very fully described and figured by Professor Nicholls, and of which I have been able to examine specimens kindly sent by Mr. L. Glauert, branched "accessory branchiae" are present on some of the segments of the peraeon. Similar branched structures are present in a specimen

that I have recently examined from Mr. Kosciusko, and which is intermediate in its characters between *N. fultoni* and *N. spenceri.* I have, however, not seen any accessory branchiae in the species now being described.

I give below a brief specific diagnosis followed by a more detailed report.

Neoniphargus westralis sp. nov. Figs. 1-3.

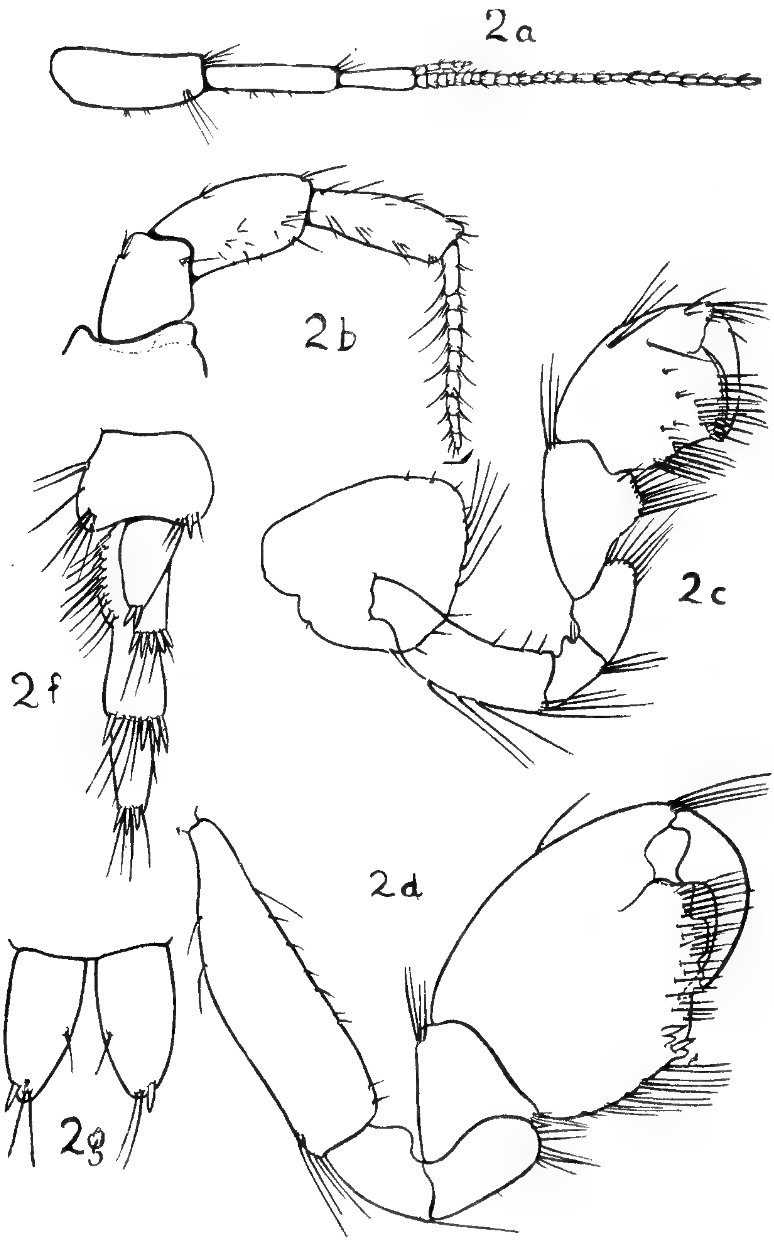
Specific Diagnosis.—Segments of the urus with a few dorsal setules. Eyes absent. Antenna 1 about half the length of body. Antenna 2 very stout and almost pediform in male, slender in female. Gnathopod 2 much larger than gnathopod 1 in the male, and with palm of propod oblique and irregularly lobed; gnathopod 2 in female only slightly different in size and shape from gnathopod 1. Uropod 3 with basal joint broad, outer branch somewhat elongated, distinctly two-jointed and bearing in the male, but not in female, on distal portion of the first joint a slightly convex expansion fringed with long setules. Telson cleft to the base.

Length of largest specimens about 8 mm.

Locality.—Darlington, Western Australia.

The general shape of the body and of the appendages presents no special peculiarities in the female. The first antennae are practically the same in both sexes and have the accessory flagellum rather longer than in some of the other species; in the specimen drawn it consists of five joints (Figs. 2a). In the male the second antenna is very stout and much shorter than the first; the last joint of the peduncle is slightly shorter and more slender than the preceding; both being provided with setae as shown in the figure (Fig. 2b); the flagellum consists of about ten joints and is rather more than half the length of the peduncle. In the female the second antenna is much more slender though the relative proportions of the joints are about the same as in the male (Fig. 3a).

In the first gnathopod of the male (Fig. 2c) the propod is considerably longer and somewhat stouter than the carpus; the palm is nearly transverse and slightly convex, the finger fitting closely down upon it, and the angle of the palm is not produced into a definite lobe as in *N. branchialis* Nicholls and other species. The second gnathopod in the fully developed males (Fig. 2d) is much stouter than the first, the propod being particularly large, the carpus reduced to the usual triangular shape associated with large propods; the palm is somewhat oblique with irregular processes and is defined by two stout setae, the finger is somewhat shorter than the palm and strongly curved. In younger males the palm is more regularly convex and the finger more slender and less curved (Fig. 2e). In the female there is little difference in the first gnathopod from that of the male. The second gnathopod, however, is much more slender than in the male, and approaches much more nearly to that of the first gnathopod. (Fig. 3b).


2a
2b
2c
2f
2d
2g

The peracopoda and the pleopoda show the normal structure of the genus.

The first uropod has the peduncle considerably longer than the branches. In the second the peduncle is longer than either of the branches, the outer of which is shorter than the inner. The third uropod (Fig. 2f) has the basal joint short and broad, nearly twice as broad as long, the outer branch is about four times as long as the peduncle and is distinctly two jointed, the second being about half the length of the first which bears a transverse row of stout setules so that it appears partially divided near the middle. The outer margin of the basal portion of the first joint in the male is somewhat convex, forming a slight lobe or projection fringed by a definite row of about ten long setae. The inner branch is about half the length of the first joint of the outer and tapers towards the extremity which bears two stout setules.

In the female the fringed lobe on the distal portion of the basal joint is quite absent, but in other respects the appendage resembles that of the male. (Fig. 3c).

The telson is divided to the base, each lobe tapers somewhat posteriorly, the lateral margins being slightly convex; at the extremity of each is a stout setule and two slender hairs and there is a slender setule about the middle of the inner margin. (Fig. 2g.)

I wish to express my thanks to Mr. L. Glauert, of the Public Museum, Perth, for sending me the specimens; to Dr. Calman, of the British Museum, for the drawing reproduced as Fig. 1, and for other assistance, and to Miss Beryl I. Parlane, one of my students, for the preparation of the other figures.

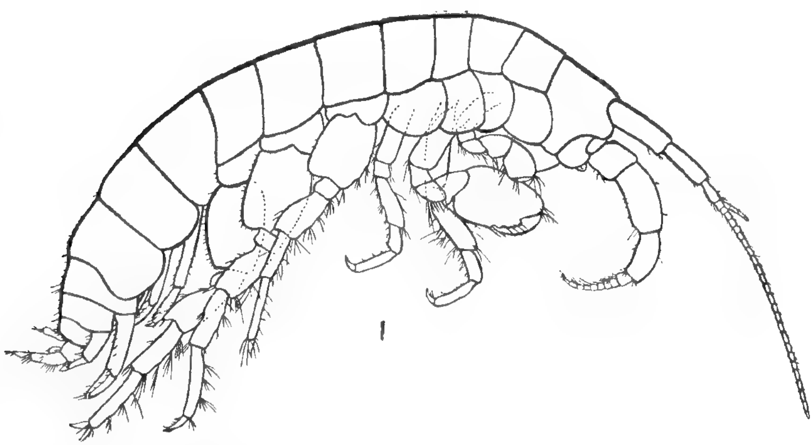


Fig. 1. *Neoniphargus westralis*, male.
Side view of whole animal. (From a drawing by Dr. W. T. Calman).

EXPLANATION OF PLATES.

IV.

2. *Neoniphargus westralis*, male.

    a. First antenna.

    b. Second antenna.

    c. First gnathopod.

    d. Second gnathopod (of adult male).

    f. Third uropod.

    g. Telson.

V.

2e. *Neoniphargus westralis*, second gnathopod (of younger male than in 2d).

3. *Neoniphargus westralis*, female.

    a. Second antenna.

    b. Second gnathopod.

    c. Third uropod.

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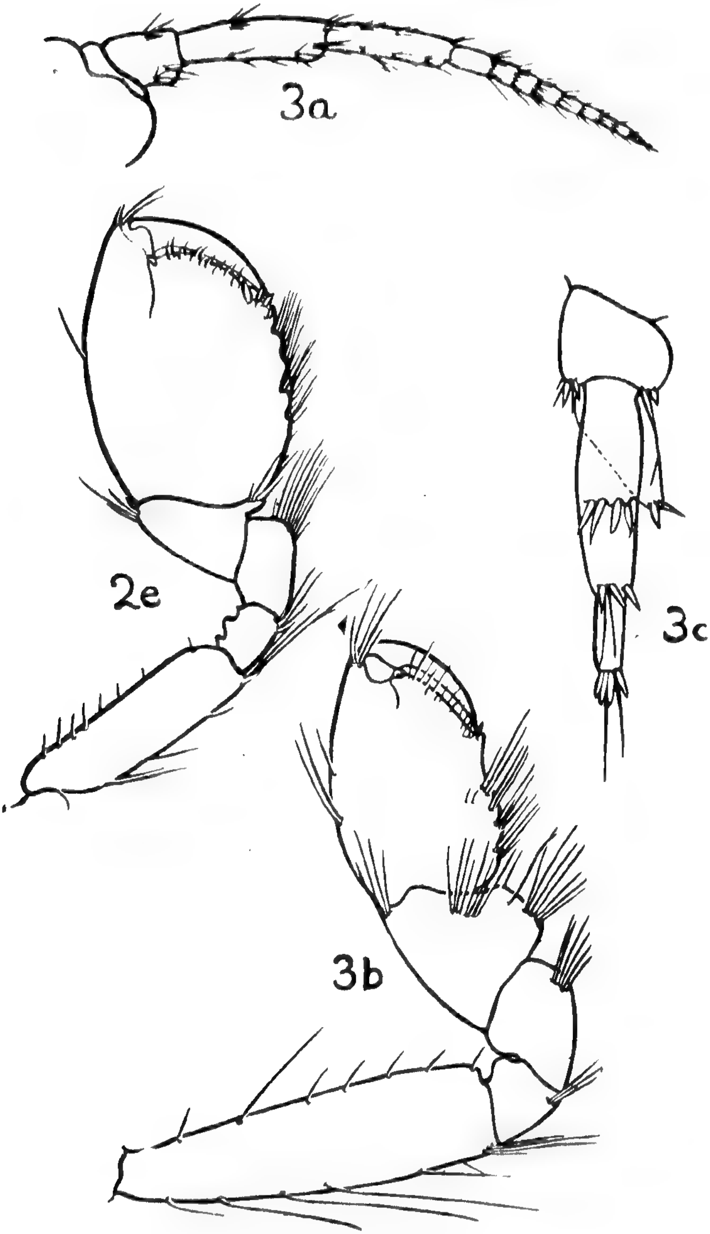
3a
2e
3c
3b

Notes on "Blind Grass" or "Candyup Poison," (Stypandra imbricata R. Br.) and certain other species that have been confused with it. By **Edwin Cheel,** Curator, National Herbarium, Botanic Gardens, Sydney.

(*Read*, June 9, 1925. *Published*, July 4, 1925.)

In Robert Brown's Prodromus, p. 279 (1810) five species of Stypandras are described, two of which are natives of of Western Australia, and the other three are natives of the Eastern States. The *Stypandra scabra* of Robert Brown has been referred to the genus Agrostocrinum by modern workers, and *S. imbricata*, the only other species from Western Australia described by Brown, has been reduced by several authorities as a synonym of *S. glauca*, a native of New South Wales and Victoria.

Brown's descriptions of these two species are in Latin, and may be freely translated as follows:—

Stypandra glauca R. Br. Leaves all distinctly turned back, the sheathing base or margin reflexed.

Stypandra imbricata R. Br. Leaves imbricate, the sheathing base with simple margins.

Since Brown's Prodromus was published, five additional species have been proposed, viz.: *S. frutescens* Knowl et Weste (8a); *S. propinqua* A. Cunn (4); *S. grandiflorum* Lindl. (9); *S. virgatum* Endl. (5); and *S. scoparium* Endl. (5). Mueller (12) includes all the above as synonyms under *S. glauca*. Baker (1), however, reduced *S. propinqua* of A. Cunningham to a variety of *S. glauca*, and includes *S. virgata* of Endlicher under the var. propinqua as a synonym. Bentham (2) evidently regarded the Western Australian plant distinct from those of the Eastern States, for we find that, after quoting specimens from King George's Sound and Lucky Bay and eastward to Cape Legrand, he states that it "is a variety with narrower, crowded leaves, which, however, passes gradually into the common form."

In connection with *S. grandiflora* of Lindley, Bentham regarded it as a "luxuriant variety (of *S. glauca*) with a perianth 8 or 9 lines long." *S. scoparia* of Endlicher is also regarded by

Bentham (2) "as a variety (of *S. glauca*) or perhaps only an old state with very numerous short lateral branches and densely tufted narrow leaves."

Maiden (10) evidently regarded the Western Australian plants as belonging to *S. glauca*, and published the following remarks concerning some specimens sent by Mr. Ash from Western Australia: "This is a herb which is said to cause animals that have fed on it to go apparently blind and run into any sort of object. It seems to be the least fatal of all the poison plants. It is slower in taking effect. It is found in the vicinity of the South Coast." Mr. Maiden further states that "this plant is common in the neighbourhood of Sydney, the Blue Mountains, and many other parts of this colony, but I have never heard of it having been reported as a poison plant here. But in Western Australia it is much more abundant than it is with us, and it has so frequently and so consistently been reported as the cause of 'Blind Disease' in sheep, that there appears no room to doubt its dangerous nature." In a subsequent paper by Mr. Maiden (11) the New South Wales plants are again referred to under the title "Is *Stypandra glauca* R. Br., a Poisonous Plant?"

Then we have a reference to it by Guilfoyle (6), who evidently regards the Western Australian plant distinct from those from the Eastern States, as we find that he lists it under the name *S. glauca* var. *imbricata*, using the common names "Blind Grass" or "Blue Spray." It is interesting to note, however, that Guilfoyle also lists *S. glauca* for Western Australia and other States, using the common names "Greyish-green-leaved Stypandra," "Candyup Poison," as well as "Blind Grass" and "Blue Spray" for this latter species. It may be that *S. grandiflora*, which is also a native of Western Australia, has been confused with *S. glauca*, as this has a much closer resemblance to *S. glauca* than *S. imbricata*.

In 1921 Herbert (8) refers to the "Blind Grass" (*Stypandra glauca*) and gives the following interesting particulars concerning it: "Blind Grass is a lily, and except for its flower, might easily be mistaken for a grass. It grows amongst granite rocks throughout the Darling Ranges and extends far into the drier areas of the wheat belt. It produces blindness in stock, and ultimate death, though deaths are rather uncommon. Stock eating the plant become very poor, partly due, perhaps, to their not being able to forage as well when blind. Paralysis and finally death follows on a continued diet. Laboratory tests on rats bore out field observations. Two rats fed with the ground-up air-dried leaves mixed with pollard became blind in two days. On each day about two grains of leaves were eaten. Partial paralysis followed, but the rats did not die after a week's treatment. Protracted feeding may, however, have resulted fatally. *Stypandra*

glauca is also found in the Eastern States, but there has no injurious effect on stock, so far as is known. It is commonly said that in the eastern districts of Western Australia it is not injurious, but experiments with materials from Kulin Rock, which is a dry eastern locality, showed that the plant had lost none of its virulence, and the evidence of settlers in the wheat belt shows that it is as dangerous there as in the Ranges."

Having examined the whole of the material represented in the National Herbarium, Sydney, I am of the opinion that the specimens collected in Western Australia are distinct species from those of the Eastern States, and can be easily defined by characters as outlined in the following key:

Leaves conspicuously distichous and distinctly turned back at the sheathing base. Inflorescence leafy, the upper leaves similar to the basal leaves .. .. *S. glauca*

Leaves simple, embracing the stem, not turned back. Inflorescence comparatively naked or supported by ovate bracts dissimilar to the lower leaves

Leaves narrow, imbricate, more or less crowded. Flowers small, 5-7 lines .. *S. imbricata*

Leaves broad, not crowded. Flowers large, 8-9 lines long .. .. *S. grandiflora*

I have not had an opportunity of examining fresh flowers of the Western Australian plants, but feel that, quite apart from the characters given above, a close examination of the floral organs in a fresh condition will reveal other characters by which the Western Australian plants can be distinguished from *S. glauca* from New South Wales and Victoria.

It has been repeatedly reported that *Stypandra glauca* is poisonous to stock. Reports from Western Australia are very definite on the matter, especially as shown in the report published by Herbert (8). On the other hand, it has been shown by a series of feeding experiments conducted by Henry and Hindmarsh (7) that they were "unable to find any evidence that *Stypandra glauca*, as found growing in New South Wales, is harmful to live stock, but rather that the plant will support life for comparatively extended periods." In view of the conflicting evidence advanced in regard to these plants, which hitherto have been regarded as belonging to one species, it would be of some interest to conduct similar feeding experiments on the two species found in Western Australia.

The distribution of the two species from Western Australia is as follows:

Stypandra grandiflora Lindl.

Buckingham's, near Collie, F. J. Trowbridge, November, 1924.
Statham Siding, Darling Range, W. M. Carne, September, 1924.
Greenmount, R. Helms, September, 1899.
Wooroloo, Max Koch (No. 1511), September 1906.
Lowden, Max Koch (No. 1958), September, 1909.
King George's Sound, B. T. Goadby, August, 1898.
Albany, H. E. Sheath, November, 1904.

Stypandra imbricata R. Br.

Brookton, G. S. Railway, S. G. Maynard, communicated by W. C. Grasby as a supposed poisonous plant, September, 1916.
Moora River, E. Pritzel (No. 575).
Warangering, R. Helms, November, 1891, with the leaves shorter and more or less clustered.
Greenmount, R. Helms, August, 1897.
Perth, Dr. J. B. Cleland, September, 1908.
Cunderdin, Dr. J. B. Cleland, September, 1908.
Albany, H. Sheath (H. Sheath ex Herb. C. R. P. Andrews).
Buckingham's, near Collie, F. J. Trowbridge, November, 1924, ex Herb. Department of Agriculture, W.A.
Wongan Hills, W. M. Carne and C. A. Gardner, September, 1924.
Statham's Siding, Darling Range, W. M. Carne, September, 1924.
York, A. J. Monger, October, 1924.

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Australian Scorpionidea by L. Glauert, F.G.S.

PART I.

(*Read* November 11, 1924. *Published* July 20, 1925.)

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INTRODUCTION.

The earliest records of Australian Scorpions are to be found in the works of C. L. Koch (1837-1850), Thorell (1876-1877), and Count Keyserling (1884-1889), where a few odd species are described. Numerous additions to the fauna were made by Mr. R. I. Pocock in a number of papers, which appeared in the Annals and Magazine of Natural History from 1888 to 1902.

In 1899 Prof. K. Kraepelin brought together all the available information in Part 8 of Das Tierreich, Scorpiones und Pedipalpi, a work of the greatest importance, which has been taken as the basis of the present paper. The classification there proposed has been adopted, and the keys provided have been widely drawn upon in the following pages. Kraepelin here recognised six genera (*Isometroides, Archisometrus, Isometrus, Urodacus, Hormurus,* and *Cercophonius*), nineteen valid species, and one doubtful species.

To this list, Pocock's paper of 1902 (A.M.N.H. (7) VIII.), added three species, *Urodacus spinatus, U. simplex,* and *U. subarmatus*. The results of Kraepelin's examination of the collection made in South-Western Australia by Drs. Michaelsen and Hartmeyer, were published in 1908, and increased the known species by four: *Urodacus hartmeyeri, Cercophonius michaelseni, C. granulosus,* and *C. sulcatus*. In 1911 Mr. A. S. Hirst described a remarkable *Lychas* from Central Australia, which he made the type of a new subgenus, *Lychas* (*Hemilychas*) *alexandrinus*. This new form bears a striking superficial resemblance to the rare *Isometroides,* a genus widely distributed in Australia, but not often seen in collections.

Sarasin and Roux, in their work, "Nova Caledonia," include in Zoology Volume I. (1914) a contribution by Kraepelin on the Scorpions and Pedialpi, in which is to be found a detailed description of the genus *Hormurus.* This description and Dr. Kopstein's results in the paper "Die Skorpione des Indo-Australischen Archipels . . ." published in the Zoologische Mededeelingen of the Rijks Museum, Leyden (1921), have been of the greatest assistance to me when dealing with the specimens of *Hormurus* in the collections before me.

Kraepelin's paper on the Scorpions collected in Australia, 1910-1913, by Dr. E. Mjoberg, appeared in 1916. The collection contained 44 specimens belonging to 14 species, four of them new, *Lychas mjobergi, L. spinatus, Urodacus fossor,* and *U. granifrons* (not of Pocock, 1898). The present paper is submitted as a contribution to our knowledge of the Scorpions of Australia. It is the result of a careful examination of the specimens in the Western Australian Museum, and of collections kindly forwarded to me for study from all parts of Australia. This extensive material contained examples of practically all the recorded species, and included a number of specimens new to science. The various species have been described according to a uniform plan, and keys inserted for the rapid determination of the families, genera, and species known to occur in Australia and Tasmania. The synonymy is mainly restricted to publications which appeared subsequent to Professor Kraepelin's Monograph of 1899.

The Directors of the Australian Museum, Sydney; the National Museum, Melbourne; the Queensland Museum, Brisbane; and the Tasmanian Museum, Hobart; the Curator of the Macleay Muesum, University of Sydney, and Professor F. Wood Jones, of Adelaide, generously placed in my hands the Australian specimens contained in their collections.

Professor W. Michaelsen, of the Natural History Museum, Hamburg, and Dr. F. Kopstein, of Ambon, Dutch East Indies, by forwarding literature not available here, have enabled me to solve several problems of distribution.

To all these kind friends I acknowledge my indebtedness and express my thanks.

DEFINITION OF TERMS.

On account of the confusion in the nomenclature of parts of systematic importance, it is advisable to explain the terms used in the present paper. The *body* of the Scorpion is considered to consist of two parts, the *trunk* and the *tail.* The *trunk* bears on its anterior upper surface a chitinous plate, the *carapace.* Near the middle of this *carapace* are two *median eyes,* usually placed upon a

raised *ocular tubercle,* and close to the antero-lateral angles are a group of smaller *lateral eyes,* which, in Australian species, number from two to three in each group. The area between the median eyes and the two groups of lateral eyes is known as the *inter-ocular triangle.* In some forms the carapace bears several more or less longitudinal *keels;* they are the *anterior median keels* in front of the ocular tubercle; the *central median keels,* just behind the ocular tubercle; and the *posterior median keels,* near the posterior border of the carapace.

The *front* may be divided into two *frontal lobes* by a more or less pronounced emargination, the *median notch* or *frontal notch,* and a groove, the *median sulcus,* may extend from the frontal notch to the posterior border, often widening behind to form a *triangular depression.* On the ventral surface behind the basal (coxal) joints of the second pair of legs, and in front of the *genital operculum,* is the *sternum,* the shape and size of which are of great importance. The rest of the trunk is the *abdomen;* it is covered dorsally by seven plates, the *tergites;* these may be smooth or may bear one or more keels, a *median keel* and *lateral keels;* the tergites are connected by soft elastic chitin with their corresponding ventral plates, the *sternites.* The first sternite bears the *genital opening* covered by the *genital operculum;* the second carries the comb-like organs or *pectines* in whose structure four portions are distinguishable, the *anterior lamellae,* the *middle lamellae,* the *teeth,* and, in some genera, the *fulcra,* a series of small pieces placed between the basis of the movable teeth.

The third, fourth, fifth and sixth sternites, referred to as the first, second, third and fourth in this paper, bear the *stomata,* or paired openings leading to the lung-books; the last segment (really the first segment of the metasoma) is without stomata, but often carries more or less well-marked *median* and *lateral keels.*

The *tail* consists of five *segments* enclosed in complete hard chitinous rings, and a *postanal segment* bearing the sting. The upper surface of the first four segments usually bears a *sulcus* flanked by the *superior keels;* on the ventral surface is the *inferior keel,* which may be single or duplicated owing to the presence of a *median sulcus;* the lateral surface usually carries a *supero-lateral* and an *infero-lateral keel,* and may be more or less completely subdivided by the development of an *accessory lateral keel.* The *fifth caudal segment* may agree with the rest in the disposition of its keels, or may differ greatly; its ventral surface is without a sulcus, and usually bears a single median *inferior keel,* which may become forked posteriorly; this segment bears the anus. The *post-anal segment* is more or less globular at its base, forming a *vesicle,* and terminates in a fine curved point, the *aculeus;* the presence or absence of a *tooth* under the *aculeus* is of systematic importance.

The *appendages* comprise a pair of *chelicerae* or *mandibles,* a

pair of *pedipalpi*, and four pairs of walking *legs*. The three-jointed *cheliceras* have the first joint small, the second strongly developed, and bearing internally at its distal end a projection which forms the *immovable* or *fixed finger;* the third joint, or *movable finger,* is external and both fingers are armed with teeth one or more rows. The *pedipalpi* consist of six joints, the *coxa, trochanter, humerus, brachium,* the *hand* with the internal *immovable* or *fixed finger,* and the terminal joint, the external *movable finger.* The keels on the *humerus* and the keels and pores on the *brachium* are often of systematic value. In some forms the upper surface of the *hand* is uniformly rounded, whilst in others a *finger keel* divides it into two flattish surfaces, the inner of which may be subdivided by an *accessory keel; inner* and *outer keels* are also often present, separating the upper from the lower surface; keels may also be developed on the lower surface of the hand. The biting edges of the fingers are furnished with one or more rows of minute *teeth,* arranged characteristically in the different genera. The *ambulatory legs* are seven jointed, the joints being known as the *coxa,* the *trochanter,* the *femur,* the *patella,* the *tibia,* the *protarsus,* and the *tarsus.* Of these, the three terminal joints furnish highly important characteristics; the *tibia* may bear a *tibial spur* at its lower distal extremity, and from the soft membrane between the *protarsus* and *tarsus* may issue one or more *pedal spurs.* The *protarsus* may bear *dorsal spines,* and the *tarsus* be variously furnished on its lower surface with *hairs, bristles, spurs* and *teeth;* this joint usually bears a pair of *movable claws* at its distal extremity, and may project in a *claw lobe* over the base of these; it sometimes also carries *lateral lobes,* which may or may not be toothed.

In addition to its armature of setae, spines, teeth granules, and keels, the surface of the body and limbs may bear fine *punctures,* coarse *setiferous pores,* as well as the more highly specialised sense organs, the trichobothria or "auditory hairs" of Kraepelin; these last are circular and crater shaped; they are surrounded by a raised ring, usually paler in colour, and from each of them issues an extremely fine hair, the diameter of which is from one fifth to one-fourth of that of the aperture at the base of the depression. These sense organs are usually present on some of the joints of the pedipalpi.

The *measurements* given throughout the paper are in millimetres.

The *Sexual Characters.*—As a rule the males can be distinguished by their smaller trunk, more pronounced granulation on the carapace and tergites, greater development of the keels on the hand, longer pectines and more numerous pectinal teeth. The genital operculum of the male is always divided.

Further particulars are to be found in the descriptions of families and genera in the following pages.

SYSTEMATIC DESCRIPTION OF THE AUSTRALIAN SCORPIONS.

The Scorpions known to occur in Australia belong to the families *Buthidae*, *Scorpionidae*, and *Bothriuridae*. Of these the first two are widely distributed, whilst the third is confined to Southern South America and Australia south of the 27th parallel.

KEY TO THE AUSTRALIAN FAMILIES.

A. Sternum represented by two small transverse plates, at times hardly visible; middle lamellae moniliform; feet with two pedal spurs. Size, small, less than 45 mm. .. .. *Bothriuridae*

B. Sternum at least half as long as broad, often longer than broad, middle lamellae never moniliform.

- A1. Sternum small, triangular or (rarely) pentagonal, feet with two pedal spurs; tibial spur present on the third and fourth legs in some genera; tooth often present under the aculeus. Hands rounded, fingers long. Size small, less than 45 mm. .. .. *Buthidae**

- B1. Sternum large, markedly pentagonal; feet with one pedal spur; no tibial spurs; no tooth under the aculus. Hands generally keeled. Size medium or large, up to 120 mm. *Scorpionidae*

Family BUTHIDAE.

Buthidae, E. Simon, 1879, Arach, France. VII.—p. 92.

Sternum small, triangular, truncated anteriorly or sub-pentagonal. Legs with inner and outer pedal spurs, the outer sometimes duplicated. Tibial spurs may be present on the third and fourth legs; lateral lobes absent. Hands rounded, with or without keels, fingers long. A tooth present under the aculeus in some genera.

Sexual Characters: The male with the tail and pedipalpi usually longer and thinner or much thicker and scarcely longer; pectines longer. Genital operculum divided in both sexes.

Key to the Sub-Families.

A. Tibial spur *present* on the third and fourth legs. .. *Buthinae*

B. Tibial spur *absent* on the third and fourth legs .. *Centrurinae*

Sub-Family **Buthinae.**

Buthinae, K. Kraepelin, 1899, Das Tierreich Lief 8. Scorpiones und Pedipalpi, p. 6.

Tibial spur present on the third and fourth legs. The immovable finger on the chelicerae below, with two, one or no teeth.

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* In some of the *Buthidae* the male attains a length of 70 mm. owing to the great development of the tail.

Key to the Genera.

A. Tooth under the aculeus strong, triangular, pointed or small. *Lychas*

B. No tooth under the aculeus, vesicle long and slender, merging gradually into the curved aculeus .. .. *Isometroides*

Genus **Lychas**. C. L. Koch, 1850.

Lychas. C. L. Koch, 1850. Uebers. des Arachnidensystems. V., p. 92.

Archisometrus Kraepelin 1891. Mitt. Mus. Hamb. VIII, p. 75.

Archisometrus Kraepelin 1899. Das Tierreich Lief 8, p. 41 (and synonymy).

Lychas Kraepelin. 1908. Fauna Suedwest Australiens II. Lief 7, p. 87.

Lychas Kraepelin. 1916. Ark. Zool. K. Svensk Vetensk. Ak. X, No. 2, p. 22.

A tooth on the lower edge of the immovable finger of the chelicerae. Tibial spurs on the third and fourth legs. Tooth under the aculeus. Tergites with median keel, rarely with indications of lateral keels. Carapace keelless or with keels weakly developed; front horizontal, slightly emarginate. Sternum longer than broad, triangular. Fingers of the pedipalpi with few, non-overlapping inclined series of teeth, each series flanked internally and externally by a single enlarged lateral tooth*. Caudal segments (except in *Hemilychas*), all keeled.

Key to the Sub-Genera.

A. Fifth caudal segment normally keeled .. .. .. *Lychas*

B. Fifth caudal segment smooth and shining, punctured keelless .. .. *Hemilychas*

Subgenus **Lychas.**

Key to the Species.

A. Tergites with indications of lateral keels.

A.1 Third caudal segment with 10 keels, pectines with 11-12 teeth .. .. *L. bituberculatus* (Poc.)

B.1 Third caudal segment with 8 keels, pectines with 20-21 teeth .. .. *L. jonesae* n. sp.

B. Tergites without indications of lateral keels.

C.1 Tooth under the aculeus minute, pectines with 22 teeth .. .. *L. mjobergi* Kr.

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* The basal series of teeth, in certain species, has two enlarged external lateral teeth. See below.

D.1 Tooth under the aculeus of medium size, truncated, wider than high, no dorsal tubercle.

A.2 Variegated, markings as in *L. marmoreus,* general colour above ochraceous orange with fifth caudal segment darker. Vesicle longer, almost parallel sided, dull keeled .. .. .. *L. annulatus* n. sp.

B.2 Colour uniform tawny, fourth caudal segment darker. Vesicle shorter, swollen, shining, keelless .. .. *L. truncatus* Gl.

E.1 Tooth under the aculeus large, much higher than wide, usually with dorsal tubercle.

C.2 Third caudal segment with 10 keels.

A.3 Terminal tooth of superior caudal keels not enlarged, or but slightly so. Basal series of teeth on movable finger of hand with 1 enlarged external lateral tooth .. .. .. *L. marmoreus* (Koch)

B.3 Terminal tooth of superior keels enlarged, erect. Basal series of teeth on movable finger of hand with 2 enlarged external lateral teeth .. .. *L. spinatus* Kr.

D.2 Third caudal segment with 8 keels.

C.3 Terminal tooth of superior keels of first three caudal segments much enlarged, erect. Fingers on hand of male lobed. Trunk, uniform brownish. Pectines with 19-23 teeth *L. armatus* (Poc)

D.3 Terminal tooth of superior keels of first three caudal segments hardly enlarged. Fingers on hand of male not lobed. Trunk variegated. Pectines with 10-17 teeth *L. papuanus* (Thor)

Lychas marmoreus (C. L. Koch) 1845.

Tityus marmoreus C. L. Koch 1845. Arachnida II, p. 36.

Isometrus variatus Thorell 1877. Atti. Soc. Ital. XIX, p. 136.

Isometrus thorelli Keyserling, 1885. Arachn. Austr. II, p. 12, pl. 2, fig. 1.

Archisometrus marmoreus Kraepelin, 1899, Das Tierreich, Lief 8, p. 49 (and synonymy).

Lychas marmoreus Kraepelin, 1908, Fauna Sudwest-Austr. II, Lief 7, Scorpiones, p. 87.

Lychas marmoreus Kraepelin, 1916. Ark. Zool. K. Svensk. Vetensk. Ak. X, No. 2, p. 26, figs. 3a, b, c.

Colour, rather variable, general colour brownish; ground

colour yellowish more or less obscured by brown or blackish markings which may give the abdomen a checquered appearance or resolve themselves into irregular blotches or marblings; tail usually paler than the trunk, marbled blotched, or with the keels only pigmented with brownish; fifth segment and vesicle often dark brown with or without rows of pale ocelli on the intercarinal spaces. Pedipalpi and legs paler yellow, marbled, blotched or banded with dark brown; hand pale yellow, often with a few dark longitudinal bands or irregular markings; fingers dark brown basally, yellowish towards the tip. Under surface variable, pale yellow, yellow dusted with darker, or yellowish with dark blotches and marblings. The darker areas on the carapace and tergites are usually more coarsely granular, the lighter areas being often finely granular or even smooth.

Carapace coarsely granular, the larger granules behind the ocular tubercle forming a pair of indistinct median keels, posterior median keels more pronounced, granular, superciliary crest coarsely granular, short, its length less than three times the horizontal diameter of the eye: median sulcus with fine granules, smooth when crossing the ocular tubercle. *Tergites* dull, coarsely granular with subdenticulate median keel and no indications of lateral keels, last with five granular keels, the median weak, abbreviated posteriorly, lateral keels regularly granular, the submarginal terminal granule of the inner pair not enlarged, outer pair shorter, not reaching the posterior margin of the tergite; the inner pair often persist to the anterior margin. *Sternites* variable, the third and fourth may be finely granular laterally, fifth granular throughout with four subdenticulate keels. *Tail* moderate, first three segments with ten keels, the accessory keel often weak on the third, but persisting to the posterior margin, fourth segment with eight keels, the accessory keel sometimes represented by a longer or shorter row of coarse granules, the terminal granule of the upper keels somewhat enlarged particularly in the male, inferior keels regularly granular. Intercarinal spaces dull, finely granular below the granules, coarser above. Fifth segment with five granular keels, intercarinal spaces with finer and coarser granules, the larger roughly aligned inferiorly, absent on the convex upper surface which is closely covered with fine granules. *Vesicle* rather shining, with indistinctly granular ventral and lateral keels, intercarinal spaces with scattered granules, sulci smooth. *Aculeus* fairly long and curved. Tooth under the aculeus strong, slightly compressed laterally, obtusely pointed, with or without a dorsal tubercle. *Pedipalpi*-Humerus with granular keels and granular intercarinal spaces, the granules larger above. Brachium with granular keels above, intercarinal spaces finely granular, lower surface very finely granular, anterior surface with an arched crest bearing several strong distally directed teeth.

Hand rounded, smooth, with indistinct finger keel, fingers long and curved, the basal series of teeth on the movable finger with one enlarged external lateral tooth. *Legs* granular with granular keels. *Pectines* with from 13 to 21 teeth, the females have shorter and less numerous teeth than the males. *Dimensions,* length up to 35. (Trunk to tail as 1 to 1½.)

Distribution: New Guinea and practically the whole of Australia.

Remarks: Professor Kraepelin has distinguished a number of varieties, one of which *L. m. marmoreus* has a range extending from New Guinea through Queensland, New South Wales, Victoria, and South Australia to South Western Australia as far north as the vicinity of Moora and Boorabbin, the others are much more restricted in their distribution. The material before me, whilst enabling me to extend the range of some of the forms, allows me to confirm the conclusions arrived at by Professor Kraepelin in his valuable paper of 1916. His key is translated and reproduced below.

Key to the Varieties.

A. Sternites dull, with a small subtriangular shining area near the posterior border of the third sternite. Each tergite usually with three pale yellow markings posteriorly between the median keel and the pale lateral margin. Sternites usually more or less pigmented with darker. Pectines with 13-17 teeth.

A.1 Pectines and coxae pale (rarely indistinct darker markings on the coxae). Tooth under the aculeus with dorsal tubercle. Anterior sternites often but faintly pigmented .. .. .. *L. marmoreus marmoreus* Koch.

B.1 Pectines and Coxae strongly marked with darker or blackish. Tooth under the aculeus conical with or without dorsal tubercle. All the sternites strongly pigmented, median paler area often small *L. marmoreus obscurus* Kr.

B. Sternites all more or less shining, the shining area not confined to the posterior margin of the third sternite. Tergites often with two pale yellow marks posteriorly between the median keel and the pale lateral margin.

C.1 Pectines and coxae with dark markings. Sternites all strongly suffused and marked with darker. Tergites with three pale yellow markings posteriorly between the median keel and the pale lateral margin .. .. *L. marmoreus nigrescens* Kr.

D.1 Pectines and coxae uniformly pale yellow. Sternites pale yellow but the posterior ones at times somewhat pigmented or suffused with darker. Tergites with two pale yellow markings posteriorly between the median keel and the pale lateral margin.

A.2 Tooth under the aculeus with dorsal tubercle, Carapace with two distinct granular posterior median keels. Fingers usually not differing much from the hand in colour. Vesicle often uniformly brown or yellowish.

A.3 Pectines with 17-21 teeth. Vesicle swollen, egg-shaped, its median keel passing evenly into the lower edge of the tubercle. Median keel of the tergites yellowish anteriorly, dark posteriorly on each segment. Fifth caudal segment with yellow ocelli .. *L. marmoreus variatus* (Thor.)

B.3 Pectines with 13-14 teeth. Vesicle more or less cylindrical, its median keel not passing evenly into the lower edge of the tubercle but forming a distinct angle. Median tergal keel often, but not always, entirely blackish. Vesicle usually uniformly reddish brown .. .. *L. marmoreus kimberleyanus* Kr.

B.2 Tooth under the aculeus conical, without dorsal tubercle. Carapace without distinct posterior median keels. Fingers more or less blackish, sharply defined from the pale yellow hand. Vesicle brown, laterally with two rows of large pale yellow ocelli, almost cylindrical, its inferior median keel not passing gradually into the tooth under the aculeus, but forming a distinct angle. Pectines with 14-16 teeth .. .. *L. marmoreus splendens* Kr.

L. marmoreus marmoreus occurs in New Guinea, Queensland, New South Wales, Victoria, South Australia and South Western Australia as far north as Moora and Boorabbin.

L. marmoreus variatus is found in Western Australia and North Western Australia.

L. marmoreus splendens is known from the vicinity of Geraldton, Moora, Tammin, Balladonia, Sandstone, and Euro in Western Australia, also from Greenly Island and Black Rock Island, South Australia.

L. marmoreus kimberleyanus occurs in the Kimberley District, North Western Australia.

L. marmoreus obscurus is a Victorian form known from the Grampian Ranges, Abbotsford and Ararat.

L. marmoreus nigrescens, confined to New South Wales, is recorded from Sydney and St. Peters, Penrith.

Lychas papuanus (Thor.) 1888.

Isometrus variatus var. *papuanus.* Thorell, 1888. Ann. Mus. Genova XXVI, p. 407.

Archisometrus marmoreus. Kraepelin, 1899. Das Tierreich, Lief 8, p. 49.

Lychas papuanus. Kraepelin, 1916, Ark. Zool. K. Svensk. Vetensk. Ak. X, No. 2, p. 29, fig. 4.

Colour variable, the ground colour of the trunk ranges from a pale yellow to ochraceous tawny or even darker and the markings from brown to blackish, the colour pattern much as in *L. marmoreus,* frontal lobes pale yellow, three pale yellow subrectangular markings near the posterior border of the first six tergites on each side of the median keel, and exclusive of the lateral marginal patch. Third and fourth caudal segments usually rather darker posteriorly, fifth segment considerably darker with yellowish terminal bands proximally and distally; vesicle resembling the fifth segment. Sternites yellowish with brownish markings, coxae and pectines also occasionally pigmented. Pedipalpi blotched, spotted or marbled with darker, hand yellowish with darker markings defining the keels and encroaching upon the intercarinal spaces, fingers yellowish, darker basally, the base at times almost blackish; legs blotched and marbled with darker, the dark markings often running together and enclosing circular or sub-circular yellow areas.

Carapace dull, closely granular, the keels absent or weakly developed, superciliary crest granular, distinct, median sulcus granular except when crossing the ocular tubercle. *Tergites* dull, granular, with a row of larger granules along the posterior margin of the tergite; median keel on the first segment obsolescent more strongly developed on the posterior segments, sub-denticulate, no traces of the lateral keels, last tergite wih five keels, the median weak, posteriorly abbreviated, the lateral keels with the granules increasing in size posteriorly, the sub-marginal terminal tooth on the median pair not at all or slightly enlarged. *Sternites* dull, with a smooth shining area at the posterior margin of some of the segments, third segment with a few granules at the postero-lateral angle, fourth more granular laterally with indications of granular median keels, fifth segment finely granular throughout with four sub-denticulate keels, the inner pair being the longer but not reaching the anterior margin. *Tail* short, first segment with ten keels; second segment with ten keels, the accessory keels being extremely weak; third and fourth segments with eight keels,

the lateral keel on the third segment being represented by a longer or shorter row of irregularly spaced granules; intercarinal spaces dull, more or less finely granular, the granules larger above, all four segments with the terminal tooth of the superior keels enlarged, more so in the males. Fifth segment with five granular keels and dull granular intercarinal spaces, the larger granules on the under surface roughly aligned, irregularly scattered on the lateral surfaces, absent on the dorsal surface which is convex, has a shallow smooth median sulcus with the lateral areas closely covered with fine granules. *Vesicle* egg-shaped, with obsolescent granulation on the keels and scattered granules on the intercarinal spaces. *Aculeus* strong and curved, about three-fourths the length of the vesicle; tooth under the aculeus long, strong, somewhat compressed laterally with small dorsal tubercle. The basal diameter of the tooth is equal to that of the aculeus and to the width of the intervening space. *Pedipalpi,* Humerus and Brachium normal, Hand rounded, not wider than the brachium, keelless, smooth, as long as the first two and half of the third caudal segments. Fingers long and slender, the basal series of teeth on the movable finger with one or occasionally two external lateral teeth. *Legs* normal, keeled and finely granular. *Pectines,* in the male with 14-17 teeth, in the female with 10-16 teeth. *Dimensions,* up to 40, trunk 16, tail 24; several specimens measured 36, trunk 15, tail 21.

Distribution: New Guinea, Queensland and New South Wales (Bankstown and Brawlin). The *Type* from Cape York Peninsula is in the Museo Civico, Genoa.

Remarks: Specimens from Bankstown and Brawlin in the collection of the Australian Museum extend the range of this species into New South Wales, where its presence was unrecorded.

Lychas armatus (Pocock) 1890.

Isometrus armatus. Pocock, 1890, Journ. Linn. Soc. XXIII, p. 439, pl. 11, figs. 3-3d.

Archisometrus armatus. Kraepelin, 1899. Das Tierreich, Lief 8, p. 47.

Male.

Colour, general colour from dresden brown to raw umber, trunk yellowish with darker markings as in *L. marmoreus,* but less heavily pigmented, ocular tubercle blackish, tail almost devoid of markings. the distal segments and vesicle walnut brown to sayal brown, under surface, coxae and pectines paler; legs and Pedipalpi marked with darker, fingers uniform yellowish brown.

Carapace emarginate in front, dull, thickly covered with lar-

ger and smaller granules; median sulcus almost smooth, deeper behind; ocular tubercle and the surrounding area almost smooth. Posterior median keels represented by a longer or shorter row of granules. *Tergites* dull, thickly and coarsely granular particularly near their posterior margin, first tergite with faint subgranular median keel posteriorly, the second to the sixth with a conspicuous granular median keel, seventh with an obsolescent sub-granular median keel anteriorly and two granular keels on each side, the outer reaching the posterior margin, the inner terminating behind in a sub-marginal enlarged tooth or granule. *Sternites* first three smooth and rather shining, fourth weakly and finely granular laterally, with or without indications posteriorly, of two short smooth median keels, fifth sternite weakly granular throughout, wth four subdenticulate keels which do not reach the anterior margin. *Tail* moderately strong not elongated, almost parallel sided; first two segments with ten granular keels; third and fourth with eight granular keels; all the inferior, infero lateral and accessory keels regularly and evenly granular, the supero-lateral and superior keels of the first segment more strongly developed behind than in front, terminal tooth not enlarged; supero-lateral and superior keels of second segment with enlarged terminal tooth, the superior being more prominent and sub-erect, the accessory keel on this segment weak, terminal tooth of superior keel of third segment developed into a enormously long and strong sub-erect tooth, that of the supero-lateral keel not much enlarged, accessory lateral keel on this segment represented by a row of granules anteriorly; superior keel of the fourth segment with long and strong sub-erect terminal tooth, smaller than that on the third, terminal tooth of supero-lateral keel scarcely enlarged. Intercarinal spaces weakly granular, the granules more abundant on the third segment. Fifth segment with five keels, superior keels very weakly granular, a few larger granules posteriorly, infero-lateral keels finely and evenly granular, inferior keel coarsely granular, the granules larger behind; upper surface convex with a shallow median sulcus, finely granular, lateral surface flat, finely granular, the granules more numerous near the upper margin; under surface very convex, coarsely and finely granular, the coarser granules roughly aligned on each side of the ventral keel. *Vesicle* slender, the keels on the under surface rather coarsely granular, the granules on the upper keels finer. *Aculeus* long and curved, tooth under the aculeus strong, laterally compressed with distinct dorsal tubercle. *Pedipalpi*: Humerus above with the keels granular and well developed, intercarinal spaces feebly granular, posterior surface with weakly granular keel; anterior surface with several large granules and a finely granular keel below. Brachium with three strong granular keels above, the granules coarsest on the anterior of these; anterior surface with a few large and sharp teeth, their tips directed distally, lower surface sub-costate and

weakly granular. Hand rounded and swollen, not narrower than the brachium, with a sub-granular finger keel which becomes smooth on the finger, upper surface feebly granular; fingers "long and slender, curved, sub-costate, immovable finger at the base bearing a distinct lobe, on the distal side of which is a distinct sinuation, the opposite (external superior) surface being convex to correspond with the sinuation; the movable digit sinuate and lobate to correspond with the lobe and sinuation of the immovable digit"; fingers with teeth in normal number of series, the basal having one or two external lateral teeth. *Legs* strongly granular and keeled. *Pectines* with 19-23 teeth. *Dimensions*: Total length up to 47, trunk 18, tail 29. The dimensions given by Pocock are: total length 43, trunk 15, tail 28, first segment of tail 3, width 3.5; second segment 4, width 3; third segment 4.3, fourth segment 5, fifth segment length 7, width 3; vesicle length, 3.5, width 2, height 2. Humerus 5, Brachium, 5.5 width 2; Hand width 2.5, length of hand back 3.5, length of movable finger 5.7.

Female similar to the male but less granular and with the terminal teeth on the second, third and fourth caudal segments less prominent; the hand less swollen and the fingers not lobed at the base; pectines shorter though with the same number of teeth.

Distribution: Northern Territory, Port Essington and Port Darwin. The *Type* is in the British Museum; it was collected at Port Essington.

Remarks: A specimen from the type locality, one of the two specimens before me, has two teeth external to the basal series, the other has one external tooth on the movable finger.

Lychas spinatus Kraepelin 1916.

Lychas spinatus. Kraepelin 1916, Ark. Zool. K. Svensk. Vetensk. Ak. X, No. 2, p. 32, fig. 5.

Female.

Colour, ground colour pale yellow marked with blackish as in *L. marmoreus,* Tergites with three pale subrectangular markings posteriorly on each side of the median keel (excluding the marginal patch). Tail yellow with dark markings, fifth segment and vesicle darker. Pedipalpi marked with blackish, hand with blackish longitudinal markings, fingers yellow, slightly darker basally. Sternites slightly pigmented laterally with indications of a median stripe, last sternite heavily pigmented. Pectines and coxae pale yellow. Legs mottled.

Carapace coarsely granular, posterior median keels indistinct. *Tergites* coarsely granular, with granular median keel, no traces

of lateral keels. *Sternites* rather dull but area surrounding the stigmata and the posterior margin of the second, third and fourth sternite smooth and shining; fourth sternite granular laterally with two smooth shining median keels; fifth sternite granular throughout, with four granular keels, the median pair reaching the posterior margin. *Tail* robust; superior keels of segments 1-4 with enlarged short, stout, sub-erect terminal tooth, presumably more developed in the male. Accessory keel represented on the third segment by a persisting row of granules, indicated on the fourth segment; intercarinal spaces distinctly granular, particularly on the posterior segments; under surface of the fifth segment with granules roughly aligned. *Vesicle* egg-shaped, its keels with obsolescent granulation, tooth under the aculeus strong, with dorsal tubercle, its basal diameter equal to the distance between the base of the tooth and the aculeus. Length of the *Aculeus* rather more than half the length of the vesicle (2.2 : 4). *Pedipalpi*: Humerus granular above. Brachium with three granular superior keels. Hand without distinct keels, not wider than the brachium. Fingers with six inclined series of teeth, the basal series with two external enlarged lateral teeth. Relation of width of hand to length of hand and length of movable finger as 2 : 3 : 6. *Pectines* with 18-20 teeth. *Dimensions*: total length 51, trunk 21, tail 30.

Distribution: Queensland and New South Wales? The *Type* is in the Zoological Museum, Hamburg.

Remarks: The collections before me contain no specimens from Queensland that agree with the above incomplete description. Three individuals in the Australian Museum collection (**K.48682**) from Bourke, N.S.W., are tentatively identified as belonging to this species.

Key to the sub-species.

A. Sternites dull, tail longer and robust .. *L. s. spinatus* Kr. (Q. and N.S.W.)

B. Sternites shining, tail shorter and slender.

A.1 General colour mars-yellow, variegated. Vesicle dull, intercarinal spaces granular .. .. .. *L. s. besti* (Vic.)

B.1 Colour uniform cream to tawny. Vesicle shining intercarinal spaces smooth .. .. *L. s. pallidus* (N.S.W.)

Lychas spinatus var. *besti* n.s.sp.

Colour: General colour of the trunk mars-yellow with irregular darker markings as in *L. marmoreus,* ocular tubercle and lateral eyes blackish; irregular markings on the carapace, a yellow lateral

band on the tergites and three subrectangular yellow areas on each side of the median keel close to the posterior margin of the six anterior tergites, the median keel pale anteriorly and dark behind; the last tergite yellowish and keels more or less pigmented with darker. Under surface yellowish, the last sternite with scattered darker markings chiefly laterally and posteriorly. Anterior caudal segments yellowish with darker markings on the keels, at times encroaching upon the intercarinal spaces; fifth segment dark brown with a yellow distal band, vesicle dark brown, the sulci paler; aculeus yellow basally, chestnut brown towards the tip. Pedipalpi brownish with circular yellow markings on humerus and brachium, hand yellowish, fingers blackish basally gradually passing to pale yellow at the tip.

Carapace dull, closely granular, keels absent or represented by an indistinct row of granules; superciliary crest coarsely granular, median sulcus with very fine granules. *Tergites* dull, closely granular, the granules rather larger on the darker areas, median keel sub-denticulate, stronger on the posterior segments, no indications of lateral keels; last tergite with five keels, the weak median keel short, not persisting posteriorly; lateral keels with even granulations, the sub-marginal terminal granule not enlarged. *Sternites* smooth and shining, the third and fourth with a few fine granules at the lateral margin, last sternite dull, granular throughout with four sub-denticulate keels not persisting to the anterior margin. *Tail* slender, segments parallel sided, the first three segments with ten keels, accessory keels indicated on the fourth segment. Superior keels of first four segments with enlarged sub-erect terminal tooth, largest on the third; terminal tooth of supero-lateral keels of first three segments slightly enlarged; infero-lateral and inferior keels of first four segments regularly and finely granular, the intercarinal spaces granular, the granules larger above. Fifth segment with five finely granular keels, the intercarinal spaces with coarser and finer granules. *Vesicle* dull, moderately swollen, egg-shaped with obsolete granular keels, smooth sulci and granular intercarinal spaces. *Aculeus* moderately curved, the tooth large, conical, scarcely compressed, with a very small dorsal tubercle, basal diameter of the tooth greater than its distance from the aculeus. *Pedipalpi* normal, the hand not wider than the brachium, keelless, very finely granular above; fingers about twice as long as the hand, keelless, the basal series of teeth with two enlarged external lateral teeth. *Legs* normal, keeled and finely granular. *Pectines* with from 16-19 teeth. *Dimensions* up to 44.5, trunk 19, tail 25.5; hand as long as the first two and half the third caudal segments.

Distribution: Mallee District of Victoria. The *Type* is in the collection of the National Museum, Melbourne, collected by Mr. D. Best.

Lychas spinatus var. *pallidus* n.s.sp.

Colour: From uniform cream to tawny, immaculate, ocular tubercle and area surrounding the lateral eyes blackish, interocular triangle paler than the rest of the carapace, pedipalpi and fourth caudal segment slightly darker, fifth caudal segment and vesicle distinctly darker, under surface very slightly paler throughout.

Carapace dull, closely covered throughout with larger and smaller granules, superciliary crest coarsely granular, keels obsolescent. *Tergites* dull, closely granular, the granules on each segment increasing in size posteriorly, first segment practically keelless, the rest with sub-denticulate median keel, last segment with median keels weak, abbreviated posteriorly and two pairs of lateral keels, the granules on which increase in size posteriorly; the sub-marginal terminal granule somewhat enlarged. *Sternites* smooth and shining, the first three somewhat rugose laterally, fourth finely granular near the lateral margin, fifth dull, granular throughout, with four sub-denticulate almost smooth keels which end in a pit on the posterior margin but subside before reaching the anterior border. *Tail*, slender, segments almost parallel sided, first three with ten keels, the fourth with eight keels and indications of the accessory keel. The granules on the superior keels increasing in size posteriorly, the keels terminating in a much enlarged tooth which is largest on the third segment. In the females the terminal tooth is directed backwards, in the male it is sub-erect and more developed. Terminal tooth of the superolateral keels on the first three segments also enlarged. Inferolateral and inferior keels on the first four segments regularly and finely granular. Intercarinal spaces dull, finely granular. Fifth segment with five granular keels, the granules being smaller below, intercarinal spaces dull, with numerous coarser and finer granules; superior surface convex, with a shallow median sulcus, finely granular. *Vesicle* smooth and shining, slightly swollen, with sub-granular keels and smooth intercarinal spaces bearing large pores. *Aculeus* moderately curved, short, about half the length of the vesicle. Tooth under the aculeus strong, conical, with small dorsal tubercle; the basal diameter of the tooth about equal to its distance from the aculeus. *Pedipalpi* normal, Hand practically keelless, not wider than the brachium, fingers fully twice as long as the hand, with six series of teeth, the basal series with two enlarged lateral teeth externally. *Legs* keeled, intercarinal spaces finely granular. *Pectines* with 17-21 teeth. *Dimensions*: Total length 44, trunk 20, tail 24; length of hand 6.5, of movable finger, 4.5.

Distribution: New South Wales, probably the interior. The *Types.* The description has been prepared from four specimens, two (**K13333**) in the Australian Museum, Sydney, and two without

numbers in the collection of the Macleay Museum, University of Sydney. These specimens are accordingly designated co-types.

Lychas truncatus Glauert, 1925.

Lychas truncatus. Glauert, 1925, Trans. Roy. Soc. South Australia, Vol. LXIX.

Colour: trunk uniform tawny, ocular areas blackish, limbs and tail yellowish, hand and fingers uniform with no indications of darker markings, fourth segment of the tail and vesicle rather darker; under surface uniform pale yellow.

Carapace dull, covered with coarse granulation, keels granular moderately prominent, superciliary crest well marked, coarsely granular, extending forward for a distance equal to the horizontal diameter of the eye, median sulcus granular, a row of larger granules along the posterior border of the carapace. *Tergites* dull, covered with granules which increase in size towards the posterior border of each segment; median keel sub-denticulate, obsolescent on the first tergite, chiefly developed on the hinder portion of the next five; last tergite with posteriorly abbreviated sub-denticulate median keel and four strongly granular lateral keels, the granules on which increase in size posteriorly, terminal sub-marginal granule not enlarged. *Sternites,* the anterior ones smooth and shining, the last rather dull, with a few very fine granules and four sub-denticulate keels which do not reach the anterior margin, the inner pair persist to the posterior margin. *Tail* first three segments with ten keels, fourth with eight keels, and strong indications of the accessory keels; superior and supero-lateral keels with granules increasing in size posteriorly, terminal granule somewhat enlarged on the first three segments, infero-lateral and inferior keels finely and regularly granular, superior intercarinal spaces shining, with a few coarse granules the other intercarinal spaces dull, with smaller granules; fifth segment with five granular keels, upper intercarinal surface convex, sulcus not pronounced, smooth, with a few large granules, lateral and inferior surfaces shining with larger and smaller granules; *Vesicle* short, swollen, shining, and keelless, the sulci obsolescent, with a number of large pores. *Aculeus* curved, stout, almost as long as the vesicle. Tooth under the aculeus short, strong, conical and truncated, wider than high, without any trace of the dorsal tubercle, the basal diameter of the tooth less than its distance from the base of the aculeus. *Pedipalpi* normal, hand swollen, wider than the brachium, smooth and shining without traces of keels or granulation on its upper surface; fingers long, curved, smooth, with a smooth keel on the fixed finger, the movable finger not more than twice the length of the hand-back. Basal series of teeth with two enlarged external lateral teeth. *Legs* keeled, the intercarinal spaces dull, finely granular. *Pectines* with

22-27 teeth. *Dimensions*: total length 38.5, trunk 14.5, tail 24, length of hand 5.5, less than the first two caudal segments.

Distribution: Victoria, Pyramid Hill, three specimens collected by Rev. E. H. Hennell, Sept. 18, 1890, and South Australia. The *Type* is in the National Museum, Melbourne.

Lychas annulatus n. sp.

Colour: Markings as in *L. marmoreus* but less prominent. General colour above ochraceous orange, the paler markings honey yellow, the darker markings brownish; ocular tubercle and area surrounding the lateral eyes blackish. Tail like the body, fifth segment brownish, with narrow pale proximal band and wider pale distal band. Vesicle honey yellow, Aculeus honey yellow, reddish towards the tip. Pedipalpi and legs like the body, fingers not darker than the hand, under surface uniform yellowish.

Carapace dull, granular, the granules enlarged on the inter-ocular triangle and at the postero-lateral angles. Posterior median keels represented by a row of granules; superciliary crests coarsely granular, terminating abruptly behind the eyes, produced in front, subsiding into an irregular mass of granules half way between the median eyes and the frontal margin. Frontal notch wide and fairly deep; lateral lobes rounded; median sulcus wide, shallow and granular in front of the ocular tubercle, wide deep and smooth posteriorly. *Tergites* dull, coarsely and finely granular, median keel granular, short, abbreviated anteriorly, without traces of lateral keels, last tergite with five granular keels, the median short, not persisting posteriorly, lateral keels regular, granular, serrate, sub-marginal, terminal tooth not enlarged. *Sternites* shining, rugulose, the fourth finely granular laterally, the fifth finely granular throughout with two long sub-denticulate median keels which do not reach the anterior margin, and two very short sub-denticulate posteriorly abbreviated lateral keels. *Tail* long and stout, first three segments with ten keels, the accessory keel weak on the third segment but persisting to the posterior border, fourth segment with eight keels. Inferior and infero-lateral keels sub-denticulate or finely granular, accessory and supero-lateral keels more coarsely granular, terminal tooth of supero-lateral keel hardly enlarged; superior keels with terminal tooth slightly enlarged. Inter-carinal spaces dull, granules very small or absent. Fifth segment with five keels, the inferior keels finely granular, intercarinal spaces with scattered granules. *Vesicle* slightly inflated, dull, with obsolescent granules, keels indistinct, the inferior keel passing gradually into the tooth under the aculeus, sulci scarcely discernible. *Aculeus* as long as the vesicle, moderately curved; tooth under the aculeus stout, short, truncated, wider than high, slightly compressed laterally without dorsal tubercle. *Pedipalpi* normal, hand

slightly swollen not wider than the brachium, keels absent, finger keel indicated by a row of indistinct granules. Fingers long and curved, basal series of teeth on the movable finger with one enlarged external lateral tooth. *Legs* granular, with granular keels. *Pectines* with 25 teeth. *Dimensions*: Total length 39, trunk 15, carapace 4.5, tail 24; length of hand 6.5.

Distribution: Interior of South Australia. The type locality is Kychering Soak, near Tarcoola. The *Type* is in the National Museum, Melbourne.

Lychas mjobergi Kraepelin, 1916.

Lychas mjobergi, Kraepelin, 1916. Ark. Zool. K. Svensk. Vetensk. Ak. X, No. 2, p. 24, fig. 2.

Colour: Trunk pale clay yellow with five more or less distinct rows of darker markings, the median marking more or less triangular, the apex being anteriorly. Sternites clay yellow without darker markings. Tail clay yellow with darker markings along some of the superior keels and in the median ventral sulcus; fifth caudal segment darker, with a pale distal terminal ring; vesicle yellow like the anterior caudal segments or rather darker. Pedipalpi and legs uniform clay yellow, a few darker markings on the femur distally and on the tibia proximally.

Carapace granular with granular central and posterior median keels. *Tergites* finely granular with granular median keel. *Sternites*, the first four smooth and shining with coarse punctures, fifth segment smooth with granular median keels and short granular lateral keels. *Tail* short, keels normal and granular, first three segments with ten keels, the accessory keel on the third segment abbreviated anteriorly, fourth segment with eight keels with very faint indications of the lateral keel. Granules on the superior keels of the first three segments increasing in size posteriorly; intercarinal surfaces very finely granular, the granules increasing in size on the posterior segments. Fifth segment with fine granular keels. *Vesicle* globular below, about two thirds as high as long, smooth, with obsolescent keels and rows of pores. *Aculeus* long, curved, about as long as the vesicle. Tooth under the aculeus small reduced to a small granule. *Pedipalpi*, humerus smooth above; brachium normally keeled. Hand not wider than the brachium, smooth, an indistinct granulation on the finger keel. Proportions of the width of the hand to the length of the hand-back and the length of the movable finger as 1.5 to 2 to 3.5. Movable finger with six series of teeth, the basal series with one enlarged external lateral tooth. *Pectines* with 22-22 teeth in the female. *Dimensions*: total length 34.5, trunk 13.5, tail 21.

Distribution: Kimberley District, Western Australia, found un-

der the bark of Eucalypts. The *Type* is in the Royal Zoological Museum, Stockholm.

Lychas bituberculatus (Pocock) 1891.

Isometrus bituberculatus. Pocock, 1891, A.M.N.H. (6) VIII, p. 243.
Archisometrus bituberculatus. Kraepelin, 1899. Das Tierreich, Lief 8, p. 48.

Colour: yellowish with brown markings, pale below; brachium brownish, paler distally, hand yellowish, fingers yellowish, darker towards the tip; tail yellowish like the trunk, fifth segment brownish posteriorly, vesicle darker basally, distal half of the aculeus brownish.

Carapace: coarsely granular throughout, the granules showing a distinct tendency in some parts to constitute definite keels, the posterior median keels well marked, slightly diverging in front, the median eyes large, the tubercle granular at the sides. *Tergites* coarsely granular, the median keel well marked; a tubercle on each side of the median keel on the posterior margin marks the position of the lateral tergal keels characteristic of e.g., *Buthus;* the lateral keels of the seventh tergite subequal in length, with the posterior granule a little longer. *Sternites* mostly smooth, the fourth and fifth granular at the sides; the fifth marked with four granular keels, the lateral of which almost attain the posterior margin. *Tail* moderately strong and long, the first, second, and third segments furnished with ten strong, granular keels, the fourth with eight keels and merely vestiges in front of the accessory keel, all the intercarinal spaces more or less granular; the posterior granule of the four upper keels on the first three segments and of the two superior keels on the fourth segment a little larger than the rest; the fifth segment with its intercarinal spaces coarsely and subserially granular, smooth and depressed in the middle line above. *Vesicle* of average form, distinctly granularly carinate beneath, the *Aculeus* elongate and curved. *Pedipalpi*: Humerus and Brachium with their keels strongly developed, granular, the intercarinal spaces finely granular; hand narrower than the brachium, above bearing distinctly granular keels; fingers long, slender and curved, in contact throughout their length. *Legs* granular and carinate; the posterior two pairs with small tibial spur. *Pectines* short, with 11-12 teeth. *Dimensions*: total length 16, tail 9, trunk 7, carapace 2.5, length of hand and fingers 3, length of fingers 2.

Distribution: Baudin Island, Shark Bay, W.A.

Remarks: Pocock says, "I cannot refer this specimen to any known species of *Isometrus*. Perhaps it is most nearly related to *I. variatus* of Thorell; but it appears to me to differ from this

last-named in its granularly carinate hands, its more distinctly carinate cephalothorax, and in the presence of a tubercle which marks the position of the lateral tergal keels, etc.''

The only known specimen is Pocock's type in the collection of the British Museum. This description has been prepared from Pocock's original paper which has been rather closely followed. The *Type* is in the British Museum.

Lychas jonesae n. sp.

Colour: General colour of the trunk dark umber, a few yellowish markings on the carapace, tergites almost uniform with traces of paler > < shaped markings and two pale ocelli anteriorly, first three caudal segments ochraceous tawny, the brown markings on the keels encroaching upon the intercarinal spaces, fourth segment darker with a pale yellow distal terminal band, fifth segment umber with a pale yellow distal terminal band; vesicle umber, its base and the sulci pale yellow with a few small pale ocelli laterally; aculeus orange at the base, darker towards the tip. Under surface uniform buff yellow. Pedipalpi with coxae and trochanter honey yellow slightly marked with darker, distal joints heavily marked and dusted with brown, hand rather lighter than the brachium, fingers basally slightly darker than the hand, honey yellow at the tip; legs honey yellow, the femur distally and the patella proximally heavily pigmented with brown, tarsal joints buff yellow.

Carapace dull, closely granular, median sulcus granular, smooth when crossing the ocular tubercle, central and posterior median keels granular and distinct, superciliary crest coarsely granular continued forward for a considerable distance subsiding into an irregular group of granules on the frontal lobes. *Tergites* dull, closely granular, the granules becoming larger posteriorly on each segment; first tergite with median keel obsolete, the next five tergites with median keel stronger and distinct indications posteriorly of lateral keels in the form of a row of several enlarged granules. Last tergite with five granular keels, the median weak, abbreviated behind, the lateral keels evenly granular, terminal granule not enlarged, the inner pair almost reaching the anterior border, the outer pair shorter. *Sternites*: first four smooth and shining, fifth dull, finely granuar laterally, with four subdenticulate keels, the outer pair very short, the inner pair extending about two-thirds along the sternite. *Tail* short, the trunk being as long as the first five segments, first two segments with ten granular keels, third and fourth with eight keels, the accessory keel hardly indicated on the third, quite absent on the fourth; keels granular, the superior keels with enlarged terminal granule, terminal granule of supero-lateral keel of fir•t three segments somewhat enlarged,

intercarinal spaces dull, granular, the granules very fine below. Fifth segment with five granular keels, the granules larger on the infero-lateral and inferior keels, intercarinal spaces dull, with larger and smaller granules, superior surface convex, sulcus weak, granulation fine and close. *Vesicle* smooth and shining, inflated below, keels without granulation, surface with numerous punctures. *Aculeus* long, about three fourths the length of the vesicle, curved; tooth under the aculeus long, conical with a minute, subterminal dorsal tubercle. *Pedipalpi* normal, the Humerus keeled and granular, Brachium with three granular keels above and an arched crest anteriorly with strong distally directed teeth. Hand rounded, the finger keel represented by a row of small granules, otherwise smooth or with extremely fine granules; fixed finger with smooth keel above; movable finger with one enlarged external lateral tooth to the basal series. *Legs* granularly carinate, the intercarinal spaces dull and granular *Pectines* with 20-21 teeth. *Dimensions*: total length 27.5, carapace 3, trunk 12, tail 15.5.

Distribution: Western Australia, interior, Hampton Hill Station, Bulong, near Kalgoorlie. The *Type* is in the Western Australian Museum, Perth (**1924-446**), collected by Miss F. Jones.

Lychas (Hemilychas) alexandrinus S. Hirst, 1911.

Lychas (*Hemilychas*) *alexandrinus.* S. Hirst, 1911, A.M.N.H. (8) VIII, p. 464.

Male (Description from Hirst's paper).

Colour: Fawn, except for the vesicle which is rather deep brown and much darker than the rest of the body; fingers of hand pale yellow, the hand itself being fawn coloured.

Carapace: granular throughout, superciliary crests granular, for some distance they are continued forwards and then lose themselves in irregular groups of rather large granules, and close to the anterior margin on either side some of these are arranged in a short keel-like series. Median keels comparatively well developed, especially in the posterior median pairs which are quite well marked and strong. *Tergites* granular, their lateral keels very short, even in the hinder segments, and in most of the segments they are represented by one or two enlarged granules only. Anterior *Sternites* smooth and shining, and, at most, with fine granulation at the extreme margin only. Penultimate sternite granular at the sides, but the granulation very fine except at the margin. Last sternite granular throughout and with four granular keels. *Tail* increasing in size posteriorly, last segment slightly swollen. Upper surface of segments 1-4 granular; fifth segment with the upper surface almost smooth anteriorly but the shallow excavated area in which the median groove of this segment loses itself pos-

teriorly is finely granular. Intercarinal spaces of segments 1-3 distinctly granular, the granules of those of the fourth have run together so as to form a confused network of low smooth ridges, and this causes the segment to appear a little smoother than the preceding ones, but not nearly so smooth as the fifth; the granules between the inferior median keels of the fourth are not fused to the same extent as those of the other intercarinal spaces of this segment. Caudal segments 1-3 each with ten distinct keels, those of the first and second and the upper ones of the third being distinctly granular. Terminal granule of the two upper keels of the first two segments slightly enlarged. Inferior lateral and ventral keels of the third segment smooth. With the exception of the superior, all the keels of the fourth segment are smooth, and they are weaker than those of the preceding segments; the keels of the two upper pairs are equally weak and have almost disappeared; the median lateral is still visible in the anterior two thirds of the segment, but is exceedingly weak. Fifth caudal segment smooth, shining and without any trace of keels, but furnished with large punctures. *Vesicle* smooth, shining, and with scattered punctures, the tooth under the *Aculeus* large and blunt. *Pedipalpi*: Hand furnished with granules which are distributed in an irregular manner, it has two well-marked finger keels, the part of them which is situated on the hand itself being granular, but the part on the finger smooth, an outer keel is also present on the dorsal surface of the hand, but it does not reach the apical end. Movable finger more than twice as long as the hand-back and with six median series of granules. *Pectines* with 20-21 teeth. *Dimensions*: total length 31, carapace 3.75, first caudal segment 2, fifth segment 3.75, width of first segment 2.5, of fifth segment 2.8.

Distribution: The only known specimen was collected at Alexandria in the Northern Territory. The *Type* is in the collection of the British Museum.

Genus **Isometroides** Keyserling, 1885.

Isometrus (part) Karsch., 1880, Sitzungsber. Ges. Naturf. Freunde, Berlin, p. 56.

Isometroides. Keyserling, 1885, Arach. Austr. II, p. 16.

Isometroides. Kraepelin, 1899. Das Tierreich, Lief 8, p. 40.

Isometroides. Kraepelin, 1916, Ark. Zool. K. Svensk. Vetensk. Akad. X, No. 2, p. 20.

One tooth on the lower edge of the immovable finger of the chelicerae. Tibial spur on the third and fourth legs. Carapace with anterior and posterior median keels, front horizontal.

Tergites with median keel, the last with five keels. Sternum triangular, hardly longer than broad. Sternites smooth, the last more or less granular, with four keels. First three caudal segments with inferior keels, fourth variable, fifth keelless with numerous punctures. Vesicle long, almost comma-shaped, not much narrower than the fifth segment, passing gradually into the aculeus. No tooth under the aculeus. Fingers of the pedipalpi with a long basal row of teeth, followed by five oblique overlapping series each of which is flanked externally and basally by two strong lateral teeth.

Specimens of this genus are very rare in collections; there are two specimens in the British Museum; the Zoological Museum in Berlin possesses the type of *I. vescus*, and the Zoological Museum in Stockholm has a specimen of *I. angusticaudus*, the type of which, formerly in the Museum Godeffroy of Hamburg, has now disappeared. I have seen ten specimens of *I. vescus* and two of *I. angusticaudus.*

Key to the species.

A. Fourth caudal segment with 8 well developed keels and short accessory keels, intercarinal surfaces granular. Surface of the fifth segment punctured, rugulose. Aculeus shorter than the vesicle. Pectines with 21-23 teeth *I angusticaudus.* Keys.

B. Fourth caudal segment keelless or very feebly keeled, intercarinal surfaces smooth. Surface of fifth segment punctured, smooth and shining. Aculeus as long as the vesicle. Pectines with 23-26 teeth .. .. *I. vescus* (Karsch.)

Isometroides vescus (Karsch) 1880.

Isometrus vescus. Karsch, 1880, Sitzungsber. Ges. Naturf. Freunde Berlin, p. 56.

Isometroides vescus. Keyserling, 1885, Arachn. Austr. II, p. 17, pl. II, figs. 3, 3a.

Isometroides vescus. Kraepelin, 1899. Das Tierreich, Lief 8, p. 40.

Isometroides vescus. S. Hirst, 1907, A.M.N.H. (7) XIX, p. 209.

Colour: From yellow to yellowish-brown, limbs, under surface and anterior caudal segments paler, fourth caudal segment brownish, fifth dark brown or piceous, vesicle brownish. Carapace with keels, ocular tubercle and lateral ocular areas dark brown or blackish; tergites with the median keel outlined in darker and with two or three more or less distinct sub-rectangular blackish marks on each side of the median keel at the posterior margin of each segment, on these darker areas the granules appear to be of larger size. The limbs bear indistinct darker markings; there are always

two, sometimes three, brown spots on the hand near the insertion of the movable finger. The paler segments of the tail have some of their keels pigmented, a more or less persistent dark line extends along the sulcus formed by the duplicated ventral keel.

Carapace uniformly coarsely and closely granular, the median keels moderately developed, granular, superciliary ridge more coarsely granular. *Tergites* dull, coarsely and closely granular, the median keels subdenticulate, the teeth directed backwards; on the anterior segments the keels are developed only on the posterior half of each tergite, on the posterior segments they reach the anterior margin; the last tergite with five granular keels. *Sternites* rugulose and shining, the last dull, coarsely granular with two well developed granular median keels and indications of an outer pair. An indistinct pair of short sub-granular median keels may be developed on the penultimate sternite. *Tail,* the first three segments with ten granular keels, the accessory keel less prominent on the third segment; intercarinal spaces dull, granular on the first, sub-granular on the second, rugulose on the third, except dorsally where the surfaces are distinctly granular. Fourth segment shining, punctured, keels weak, indistinct or absent, the granules not distinct but coalescing to form roughly linear ridges or irregular masses. Fifth segment keelless, smooth and shining with very numerous large punctures. *Vesicle* keelless, smooth and shining with the punctures roughly aligned. *Aculeus* curved, about as long as the vesicle. *Pedipalpi*: Humerus with three finely granular keels, Brachium with three granular keels above and a prominently arched crest; anteriorly the joints are dull, granular above; lower surfaces smooth, or with a few minute granules. Hand long and slender, narrower than the brachium, keelless, the fingers very long, quite twice the length of the hand, not gaping, with a long basal and five short, oblique, overlapping apical rows of teeth, lateral teeth much larger than the central row. *Legs* dull, and granular, the tibia and the tarsal joints dull but smooth and paler in colour, tibial spur well developed, on one specimen (**1924-544**) it is absent from the fourth leg on the left side. *Pectines* with 23-26 teeth, (**24-1033**) from Merredin has 23-23 teeth. *Dimensions*: (**1924-544**) total length 45.5, carapace 5, trunk 16.5, tail 29. Fifth caudal segment 6.5, width of same 3.

Distribution: The more arid parts of Australia; the type was obtained "in Australia," a specimen in the British Museum was collected at Kalgoorlie. There are specimens in the Western Australian Museum from Bulong (1), Southern Cross (2), Baandee (1), Kununoppin (1), Merredin (1), Tammin (1), and White Peaks near Geraldton (1). The specimen from White Peaks has the trunk brownish but differs in no other way from the specimens from Southern Cross and Tammin. A specimen has also been re-

ceived from Dudinin on the Narrogin-Narembeen Railway, another from Serpentine, on the Darling Range, near Perth.

Isometroides angusticaudus Keys., 1885.

Isometroides angusticaudus. Keyserling 1885. Arachn. Aust. II, p. 19, pl. II, figs. 4, 4a, 4b, 4c.

Isometroides angusticaudus. Kraepelin 1899. Das Tierreich, Lief 8, p. 40.

Isometroides angusticaudus S. Hirst 1907, A.M.N.H. (7), XIX, p. 209.

Isometroides angusticaudus. Kraepelin 1916. Ark. Zool. K. Svensk. Vetensk. Ak. X, No. 2, p. 21, fig. 1.

This species is very close to the preceding. It can, however, be distinguished by the distal caudal segments; the fourth has eight well developed keels and granular inter-carinal surfaces, the fifth is punctured and rugulose, not smooth, and the post-anal segment has the aculeus appreciably shorter than the vesicle. The Pectines have 21-23 teeth against 23-26 in *I. vescus*. *Dimensions*: The specimen in the British Museum, which is larger than the two specimens before me, has a total length of 41; length of tail (vesicle excluded) 23; length of fifth segment 6.5, width of fifth segment 3.5.

Distribution: Keyserling's type was from Peake Downs, Queensland; the British Museum possesses a single specimen from Port Lincoln, South Australia; a female from the Kimberley district, Western Australia, is in the Zoological Museum, Stockholm; the Australian Museum has a single specimen from the Pinnacles near Broken Hill, N.S.W., and the Western Australian Museum has a young individual from Warriedar Station near Lake Monger, W.A.

Sub-family **Centrurinae.**

Centrurinae. K. Kraepelin 1899. Das Tierreich, Lief 8, p. 64.

No tibial spur on the third and fourth legs. Immovable finger of the chelicerae, below, with one tooth. Tooth present under the aculeus.

This sub-family is represented in Australia by one genus, *Isometrus,* confined to Queensland and tropical Western Australia.

Genus **Isometrus.** Hempr. and Ehrenb. 1828.

Isometrus. Hemprich and Ehrenberg 1828. Symbolae physicae seu Icones . . . Scorpiones.

Isometrus. K. Kraepelin 1899. Das Tierreich, Lief. 8, p. 64 (and synonymy).

Fingers of the hands with five or six inclined, non-overlapping rows of teeth, each row basally with an external and an internal lateral tooth. Tergites with a single keel. The last with five keels. Tooth under the aculeus large.

Two species are recorded, the endemic *I. melanodactylus* and the cosmopolitan *I. maculatus.*

Key to the Australian species.

A. Pectines with 16-19 teeth (rarely 15). Tooth under the aculeus sharp and conical, the distance between its base and the aculeus greater than the diameter of the former. Superior keels of the caudal segments without enlarged terminal teeth. Distal segments of the tail not, or but little, darker than the trunk .. .. *I. maculatus* (Geer)

B. Pectines with 10-13 teeth (rarely 14). Tooth under the aculeus laterally compressed, the distance between its base and the aculeus less than the diameter of the former. Superior keels of the caudal segments, particularly the second and third, with enlarged terminal tooth. Distal segments of the tail darker than the body .. .. .. *I melanodactylus* (Koch)

Isometrus melanodactylus (L. Koch) 1867.

Lychas melanodactylus. L. Koch 1867. Verh. K. K. Zool. bot. ges. Vienna, XVII, p. 239.

Isometrus melanophysa. Keyserling 1885. Arach. Aust. II, p. 3, pl. I, figs. 1, 1a-1e, 2, 2a.

Isometrus melanodactylus. K. Kraepelin 1899. Das Tierreich, Lief 8, p. 68, fig. 27 (and synonymy).

Isometrus melanodactylus. K. Kraepelin 1916, Ark. Zool. K. Svensk. Vetensk. Ak. X, No. 2, p. 33.

Colour: Trunk yellowish, often with darker markings and spots, interocular triangle paler; limbs paler, the brachium darker than the humerus, hands yellowish, the fingers often blackish at the base, becoming paler towards the tip, at times scarcely darker than the hand; proximal segments of the tail yellowish, fourth and fifth darker, brownish or blackish, vesicle reddish, aculeus darker towards the point. Under surface of the trunk uniform yellowish, the proximal caudal segments with or without darker markings.

Carapace granular, keelless, median sulcus moderately developed, persisting when crossing the ocular tubercle. *Tergites* granular with granular median keel, the paler areas smooth; last tergite with a granular median keel and two pairs of granular lateral keels. *Sternites* smooth and shining, the last with two granular keels. *Tail*, caudal segments keeled, the superior keels of the second and third segments with enlarged terminal teeth, in the male very much enlarged and erect, pointed, in the female less prominent and with the point directed backwards; intercarinal spaces dull, finely granular. In the male the tail is often twice the length of the trunk, in the female but slightly longer than the trunk. *Vesicle* not narrower than the fifth segment, not inflated, *Aculeus* from one third to one half the length of the vesicle, tooth laterally compressed, short and broad, truncate, with a small dorsal tubercle. *Hands* keelless, somewhat inflated, not much if at all wider than the brachium; fingers slightly longer than the handback, with six series of teeth, the basal the longest, and six internal and seven external lateral teeth. *Pectines* with 10-13, rarely 14, teeth. *Dimensions*: Male up to 52, female up to 32; the largest male I have seen measured 49, trunk 17.5, tail 31.5.

Distribution: Eastern Queensland from Cape York Peninsula to Brisbane, also West Kimberley, Western Australia. I have seen specimens from Cairns, Endeavour River, Eidsvold and Condamine. The collection of the Macleay Museum contains several imperfect specimens from King Sound, West Kimberley in tropical Western Australia, which are very near to this species, on them the darker markings are very faint or absent and the fingers are scarcely darker than the hand. They have a stouter tail, more inflated vesicle, and distinctly stouter hands. For this Western Australian form of the species the name var. *inflatus* is proposed.

Isometrus maculatus (Geer) 1778.

Scorpio maculatus. Geer 1778. Mem. Hist. des Insectes, VII, p. 346, pl. 41, figs. 9, 10.

Isometrus maculatus. Keyserling 1885. Arach. Aust. II, p. 6, pl. I, fig. 3.

Isometrus maculatus. K. Kraepelin 1899. Das Tierreich, Lief 8, p. 66, fig. 26 (and synonymy).

Isometrus maculatus. K. Kraepelin 1916. Ark. Zool. K. Svensk. Vetensk. Ak. X, No. 2, p. 34.

Colour: General colour yellowish with more or less intense

blackish markings, the interocular triangle pale yellow. Under surface uniform yellowish.

Carapace keelless, finely granular, the superciliary crest more coarsely so anteriorly. *Tergites* dull, closely granular, each segment with a submarginal row of enlarged granules posteriorly, median keels granular; the last tergite with five granular keels. *Sternites* smooth and shining, the last granular with four granular keels. *Tail* in the male long and slender, about twice the length of the trunk; in the female about as long as the trunk; all the caudal keels granular; accessory keel on the first segment persistent on the second segment absent or represented by a short row of granules. Superior keels without enlarged terminal teeth. Intercarinal spaces finely granular, the granules most plentiful above, all the surfaces slightly concave. *Vesicle* long and slender, not strongly keeled, tooth under the aculeus, pointed and conical, with a small distinct dorsal tubercle, slightly compressed. *Aculeus* less than half the length of the vesicle, very strongly curved. *Pedipalpi*: Brachium indistinctly keeled; hand long and slender in both sexes, not wider than the brachium; fingers from once and one half to almost twice the length of the hand, with six internal and six or seven external lateral teeth. *Pectines* with 16-19 teeth, rarely 15, usually 17 or 18. *Dimensions*: Male up to 70, female up to 45. The males have the pedipalpi and tail much longer than the female.

Distribution: Widely distributed in tropical and subtropical lands. Dr. E. Mjoberg obtained three specimens at Broome, North Western Australia; these appear to be the only authentic Australian record. The collection of the Macleay Museum contains two males from an unknown locality—presumably Australian.

Printed for the Royal Society of Western Australia by R. S. Sampson, 971-973 Hay Street, Perth.

Japan: the Geology of the Country and the Language of its People by **Edward S. Simpson,** D.Sc., B.E.

(Abstract of an address *delivered* May 12, 1925. *Published* July 30, 1925.)

In a brief introduction the geography of the Japanese Empire was outlined. The main islands with an area of 151,000 square miles stretch from Lat. 31½° to 46° and exhibit a great range of temperature. The rainfall is heavy throughout and provides innumerable rivers in a heavily wooded and unusually mountainous country.

Geology of Japan: Until Tertiary times Japan was probably part of the main continent of Asia. The backbone of the islands is of granite flanked on both sides with greenstone schists of Keewatin age passing into Huronian meta-sediments. This Archaean area occupies about 15 per cent of the whole country, and is traceable at intervals from Sakhalin right through to southern Kyushu.

Steeply inclined Palaeozoic slates and quartzites overlie the Archaean, the boundary not yet clearly defined, but trilobites and other characteristic fossils have been found in many places. Carboniferous limestones with *Fusulina* are known at Yamaguchi (Hondo) and elsewhere, but no coal of this age is known.

The south eastern portions of Kyushu, Shikoku and the Yamato peninsula are characterised by a large development of Mesozoic rocks, particularly of the Cretaceous age.

The Tertiary era was cataclysmic, Japan being separated from the mainland and opened up into several portions by rift valleys. At the same time a large number of volcanoes burst through the slates and schists from one end of the country to the other, along four main intersecting lines. These attained their zenith in Pleistocene times, many cones rising over 8000 feet, with accumulations of ashes and flows of lava which is mainly andesite, rarely basalt or liparite. Volcanic cones cover 21% of the area of the country, and Tertiary and post-tertiary sediments, including much volcanic debris, cover a further 46%.

Miocene beds yielded in 1923 about 29 million tons of black coal and hold reserves of 8000 million tons. These are chiefly in N. W. Kyushu and Southern Hokaido. The petroliferous beds of western Hondo are Upper Eocene, and yielded 157,000 tons of oil in 1923. The main metalliferous deposits are also associated with these volcanic intrusions, gold, silver, copper, zinc, and lead being important products.

Many vents are now quite extinct, but during the last 50 years 17 have been more or less violently active, the most famous being Aso and Asama Fuji, the highest (12,390 feet) has not erupted since 1707.

Innumerable hot springs are still flowing and disastrous earthquakes occur from time to time, especially in northern and central Hondo. The most recent, that of Tokyo in 1923, was by far the worst on record, causing the destruction directly by shock, or indirectly by fire, of 575,000 houses, and the death of 143,000 persons. The focus of this was 50 miles S. of Tokyo in Sagami Bay. It was caused by a sudden movement along a N. N. W. tectonic line under the influence of immense pressure from the S. E. The bed of Sagami Bay was seriously affected, about 250 square miles being depressed an average of 39 fathoms, and 85 square miles elevated an average of 45 fathoms. Slight elevations of the shore were also noted.

Japanese Language: Although the Chinese character is largely used in writing Japanese, the two languages are not of the same type or origin; Japanese belonging to the Ural-Altaic group, and Chinese to the Indo-Chinese group. Further, Chinese is isolating in structure, and Japanese semi-inflected. Just as English is written with Roman character and has added a large number of Latin derivatives to an original Anglo-Saxon stock, so Japanese has built up a primitive national language by adding many Chinese derivatives, and largely utilises the Chinese ideographs. The independent origin is easily recognised in the words representing primitive concepts, e.g., Jap. tsuki, Ch. yuerh (moon); Jap. yama, Ch. shan (mountain); Jap. futatsu, Ch. urh (two). The first important influx of Chinese words was due to the return from China of students of philosophy and crafts in the early 8th century. Continuous additions have been made since then, even now many technical terms being built up from Chinese roots as we are doing from Greek, e.g., denwa (telephone) from Chinese den (lightning) and wa (conversation).

In the last half century a large number of English scientific

proper and commercial words have been adopted in their Japanese form, e.g., Osutaria (Australia), beriru (beryl), machi (match). Occasional words are found of French, Italian, or Latin origin.

Of the far-eastern nations, Chinese had ideographs from prehistoric times. On the basis of these the Koreans devised an alphabet, but built up their words into monograms simulating Chinese ideographs. The Japanese first attempted a form of writing on the Korean model but abandoned it, and in the 2nd century adopted Chinese ideographs, applying them to identical concepts, but calling them by the Japanese names. For example, the Chinese ideograph for mountain would be used in writing by both Chinese and Japanese, but the former would read it as "shan," the latter as "yama." Chinese books were first circulated in Japan about 285 A.D.

The written language was devoid of the spoken inflexions until the 8th century, when two syllabaries were invented, viz. Hiragana by Kobo Daishi, a Japanese abbot who had studied in China, and later the Katakana by Kukai.

A syllabary is possible only to a language built up of very few syllables. The Japanese recognise 51 pure syllabic sounds, viz., the five vowels a, e, i, o, u; and 45 others formed by suffixing each of these to each of the nine consonants h, k, m, n, r, s, t, w, y. The fifty-first syllable is "un," a terminal syllable in which the vowel is almost always elided. Five further consonants are looked upon as only modifications of the pure ones, viz., g (derived from k), d (t), b and p (h), z (s), and the corresponding symbols in the syllabaries are indicated by diacritical marks, following the "pure" syllabics. This gives a total of 76 syllables in two forms, script (hiragana) and print (katakana).

In writing, the syllabics were at first only used as inflexions following a root written in Chinese. They are now, however, very largely used for all purposes, especially in manuscript, shop signs, etc.

St. Francis Xavier reached Japan in 1549 and was the first to use a romanised transcript of the language in his scriptures. His transcript was, however, quite different to the present one. It was largely adopted by the numerous converts to christianity, and was first used in a printed book (A Life of Christ) in 1591. Under the name of Romaji it continued to progress until banned by the reactionary Shoguns (military dictators) in the 18th century. In spite of this it slowly crept

into use again during the early part of the 19th century. With the Japanese renaissance (Meiji, 1868) Dr. Hepburn revised the Romaji to its present form, with European vowels, and English consonants, stabilising it by the publication of a large dictionary.

There is now a Society for the Propagation of Romaji which publishes a monthly magazine. Further, all railway station names are duplicated in Romaji, and many shop signs, etc., are treated similarly. Every school boy learns English and therefore becomes accustomed to the Roman character, and the general impression is that before long Romaji will completely supersede the Chinese ideographs and Japanese syllabics, both of which are now found freely intermixed in all newspapers, books, and public signs.

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On the Variation of Light Intensity in the Solar Corona at the Eclipse of 1922, September 21, at Wallal, by **Professor A. D. Ross,** M.A., D.Sc., F.R.S.E.

(*Read* November 11, 1924. *Published* July 30, 1925.)

Determination of the law of variation of light intensity in the corona is important in the study of the constitution of this solar appendage. Attempts to apply photometric methods at total eclipses date from 1870, December 22, when Professor Pickering used a bunsen photometer in this work.* At the eclipse of 1878, July 29, Professor J. W. Langley attacked the problem with greater success.† But, while Professor T. E. Thorpe and Sir William Abney continued the tests at the eclipses of 1886, August 29‡, and 1893, April 16§, little real progress was made until standardised photographic plates were introduced by Abney. In this method part of a plate to be used on the corona was previously impressed with a series of standard squares by photographing an artificial light through sheets of varying and known thickness of some translucent material. In this way there was obtained on the negative a scale of image densities corresponding with definite relative light intensities. These squares were first used at the eclipse of 1889, December 22, but the resulting plates do not appear to have been measured. Further plates were secured at the eclipse of 1893, April 16, and were examined by Professor H. H. Turner.* These several investigations appeared to show that the intensity of the light varied inversely as the square of the distance from the sun's limb, although the visual and photographic tests revealed very considerable discrepancies.

At the eclipse of 1922, September 21, the author decided to carry out a series of tests using two cameras of about 75 cms. focal length, the lenses being operated at $f/10$. These gave solar discs of about 7 mms. diameter, and the total space occu-

* U. S. Coast Survey Reports, 1870, p. 172.
† Washington Observations, 1876, appendix III.
‡ Phil. Trans. Roy. Soc., A. clxxx (1889), p. 361.
§ Phil. Trans. Roy. Soc., A. clxxxvii (1896), p. 433.
* Proc. Roy. Soc., lxvi (1900), p. 403.

pied by the corona and its streamers was about 3 cms. The cameras were mounted on the same polar axis as carried the Floyd telescope and spectroscopes of the Lick Observatory, and, as the author had to operate the latter instruments at the beginning and end of totality, the arrangement facilitated rapid working. Some trouble was experienced in obtaining sharp definition. The cameras were focussed at night by photographing stars, but it was evident that temperature and humidity affected the adjustment to a slight degree. In the end one camera gave perfect focus, but while the other was very slightly out of focus the result was to soften the structure apparent in the coronal streamers and so assisted in getting average values more readily.

The plates employed were Ilford Special Rapid and Wellington Antiscreen. Half-plates were cut in two, one portion to be used in photographing the corona and the other half to receive standardisation. The standard squares were obtained by exposing to a fixed light at varying distances successive portions each about 2 cms. square of each plate for the same period as was to be given to the corresponding eclipse photograph. For the fixed light an amyl acetate lamp was enclosed in a well-ventilated box with a hole 2 mms. in diameter, 25 mms. above the top of the wick, and 32 mms. in front of the flame. The flame was adjusted by the lamp microscope to the customary height of 40 mms. The standard squares were impressed by exposing the sections of the plate to the light at distances of 100, 141, 200, 283, 400, and 566 cms., this giving exposure intensities of 1, ½, ¼, ⅛, 1-16, and 1-32. These standard squares were photographed about twelve hours before the eclipse, but the plates were not developed until three to four weeks later. As experience with other plates used at the eclipse made it probable that the squares were under-exposed, a second series was impressed on the actual eclipse plates. These carried the series three terms further on the side of greater intensity. The results thoroughly justified this step, and the second series gave a completely satisfactory set of standards. Comparison with the earlier series showed that no appreciable error was introduced by the lapse of time between the eclipse photographs and the photographs of the second series made immediately before development.

Three plates were exposed in each camera, two Ilford Special Rapid and one Wellington Antiscreen plates in one camera and two Wellington Antiscreen and one Ilford Special Rapid plates in the other. In each case two plates of different type were given a shorter exposure, and the remaining plate a four-fold longer exposure.

A simple optical arrangement was devised by which two standard squares and any desired portion of a coronal photograph could be brought into juxtaposition in the field of view of a low power compound microscope, and so the intensities at selected points beyond the solar limb could be compared.

The results may be summarised as follows:

1. The inverse relation of intensity of light to the square of the distance from the sun's limb holds approximately for distances exceeding 0.2 solar radii when Ilford Special Rapid Plates are used.

2. The inverse square law is more accurate at considerable distances from the limb than near the limb. Close to the limb the intensity does not diminish so rapidly as according to the inverse square law.

3. With the Wellington Antiscreen Plates the falling off in intensity is much more gradual than according to an inverse square law, varying approximately as d to the power -3/2, where d is the distance from the limb in solar radii.

4. The rates of variation are nearly the same in all directions, the slight deviations noted being that the intensity falls off less rapidly along equatorial than along polar radii, and less rapidly along the principal streamers than along radii clear of the streamers.

It appears desirable that similar investigations should be made at several eclipses during the sunspot cycle, and the results obtained discussed along with measurements of the total light intensity of the corona.*

The author desires to express his indebtedness to Mr. W. H. Crocker of San Francisco and to Dr. W. W. Campbell of the Lick Observatory for facilities for carrying out the above tests at Wallal.

* G. H. Briggs, Astrophysical Jour., lx, No. 5, p. 273 (1924), and A. D. Ross, Monthly Notices Roy. Astron. Soc., lxxxiv, p. 660 (1924).

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The Root Parasitism of Western Australian Santalaceae by **D. A. Herbert,** M. Sc., Department of Biology, University of Queensland.

(*Read* May 12, 1925. *Published* August 10, 1925).

The Natural Order Santalaceae is one which is widely distributed over temperate, and to a lesser degree, tropical regions of the earth. In Australia it is represented by eight genera: *Thesium, Santalum, Fusanus, Exocarpus, Choretrum, Leptomeria, Omphacomeria,* and *Anthobolus.* The last four are endemic. All except *Thesium* and *Omphacomeria* have species in Western Australia.

Dr. Diels (1) in speaking of the family says:

> "The Santalaceae also are not confined absolutely to the Eremaea in Western Australia. They surround the South-West province in a narrow margin along the coast, like *Callitris robusta,* for example, or the Myoporaceae. In addition they have enriched the South-west province with some endemic species. Yet the centre of the group is undoubtedly the interior. Many species extend throughout the whole tableland without any big gaps (e.g. *Fusanus spicatus* and *Exocarpus aphylla)* and many are amongst the most common plants of the Western Eremaea."

The Eremaea is that tract of country with an average rainfall of 15-25 cm., and embraces the greater part of the interior of the State. It is true that the order forms a more important part of the formation in the Eremaea than in the moister coastal regions of the South-west but this importance is due to the numbers of the individual plants and their relatively greater size, not to the number of endemic species. They become a conspicuous feature of the vegetation, whereas their specifically more numerous, but smaller allies of the South-west where the vegetation is more luxuriant play an insignificant part in the general picture. A survey of the species in the South-west shows a greater number of species here than in the dry areas. The comparison of the distribution of the Santalaceae with that of the Myoporaceae and *Callitris robusta* is incorrect, as both these are coastal, whereas the Santalaceae are well distributed through the South-west and are continuous with the family on the Eremaea. These other forms mentioned are found both in the Eremaea and on the coast

because the same conditions of dryness occur in both regions, though one is a meteorological and the other a physiological phenomenon.

The root parasitism of several genera of the family is well known, but at the time of the investigation no enquiry had been made into the habits of the Western Australian species except the Sandalwood (2) and the Quandong (3). A brief account of the parasitic habits of the species dealt with in this paper was given in a paper (4) dealing with general characters of phanaerogamic parasites; Mr. Gardner has since examined one of these, *Choretrum lateriflorum,* and a list of its host plants is in press.

Santalum, Thesium, Comandra, and *Osyris* have long been known to derive part of their nourishment from other species. *Santalum album,* the Sandalwood, has been thoroughly investigated by Dr. Barber (5) in India. Other papers, particularly those of Rama Rao, have appeared in "The Indian Forester" with references to Dr. Barber's work and show that this species is an obligatory parasite with a wide range of hosts. Dr. Heinricher (6) of the University of Innsbruck has dealt with *Thesium, Comandra,* and *Osyris* and Dr. Margaret Benson (7) has investigated the habits of *Exocarpus cupressiformis,* an Eastern Australian species.

The last species has a wide range in the Eastern States (including Tasmania) but is only recorded from Western Australia by a doubtful specimen from Wilson's Inlet. The specimens which Dr. Benson investigated were obtained from Killara, New South Wales. The haustoria are very minute and necessitate the use of a hand lens for examination. As the same types of tissue are found in the haustoria of the Santalaceae dealt with later in this paper, Dr. Benson's nomenclature will be adhered to. Three types of haustorium-bearing roots or "necks" were met with:—

(a) A type with irregularly disposed reticulately thickened tracheides as in a *Thesium* haustorium.

(b) A type containing a strand of pitted tracheides with phloem and differing only in the number of protoxylems from the mother root.

(c) A type similar to an ordinary root but lacking phloem.

The haustorium proper consists of two parts, an outer cortical region and an inner conducting region, the "nucleus." The nucleus is shaped like an inverted flask, the neck of the flask towards the host tissue. It consists of an inner hyaline part covered with a layer of lignified cells of the vascular sheath. These form a pad at the end of the flask nearest the neck and connect with the tracheides of the neck. They are termed "phloeo-tracheides" as they differ from typical tracheides in several important par-

ticulars, and combine the structure and function of phloem and xylem. They are lined with protoplasm but contain no nucleus and are reticulately thickened and lignified, but contain no bordered pits as do the reticulately thickened tracheides of the neck.

This paper deals with the parasitism of *Fusanus spicatus.* R.-Br., *Fusanus acuminatus.* R.Br., *Leptomeria preissiana.* DC., *Leptomeria spinosa.* DC., *Choretrum lateriflorum.* R.Br., *Exocarpus aphylla.* R.Br., and *Exocarpus spartea.* R.Br.

THE GENUS FUSANUS.

This genus is limited to Australia. It was adopted by Robert Brown in the Prodromus, and subsequently united by De Candolle with the genus *Santalum.* Bentham and others, however, retain it and the system is followed in this paper.

Three species are known from Western Australia, the Sandalwood (*F. spicatus.* R.Br.) and the two Quandongs (*F. acuminatus* R.Br., and *F. persicarius.* F.v.M.). A fourth, *F. crassifolius,* occurs in the Eastern States.

The leaves of *Fusanus* are broad and the plants are not so characteristically Santalaceous in appearance as those of other Australian genera (except *Santalum*). It would be thought that they would be capable of enabling the plants to lead an independent existence, but examination of two species, *F. spicatus* and *F. acuminatus,* showed that they shared the property of root-parasitism and modified root system known to exist in *Santalum* and other genera already investigated.

PARASITISM OF FUSANUS SPICATUS. R.Br.

Fusanus spicatus. R.Br. (*Santalum cygnorum.* Miquel) is the Western Australian Sandalwood. It produces a scented wood which for burning purposes is equal to that of the Indian Sandalwood (*Santalum album*). Owing to its commercial value the Sandalwood has formed the basis of a considerable industry in the State and, though once extending through the dry interior through the Avon district to the borders of the Darling district, it has now been cut out so thoroughly that it can only be looked for in far back inaccessible districts in any quantity or attaining a good size. Preiss in 1837 collected it round York, where it was known in those days as the "Nut Tree." This name is never heard now. Bentham describes it as a tree of 30 feet, but now it is rare to find it much over 10 or 12 feet. Its regeneration is slow. Unlike *Santalum album,* which reproduces readily from root suckers as well as from seed, it usually reproduces from seed only. Its growth is slow. Trees in the Pingelly plantation showed a maximum height of 10 to 15 feet for over 20 years. It does not produce as much fruit as either *F. acuminatus* or *F.*

persicarius. These factors, combined with the rate at which the Sandalwood was cut out, resulted in the establishment of a sandalwood plantation by the Forestry Department in 1895 at Pingelly, in the Avon District. An area of typical "jam"* country was cleared and planted with sandalwood "nuts." These germinated, grew for a year, and then died. The parasitic habit of the species was not then known. More "nuts" were sown in the virgin bush, and though later the land was taken up for pastoral purposes, the resultant seedlings flourished and have now attained heights varying up to 15 feet. These results are strong indications of the root parasitic habits of the tree. Fires and browsing stock are the main enemies that the plants have to contend with before reaching maturity.

Root System: The Sandalwood produces a branching taproot and a well developed shallow placed lateral root system. These lateral roots vary in size down to about quarter of a line diameter. The smaller roots are very fleshy (Fig. 4) and in section show a large development of cortical tissue. They are very fragile and therefore difficult to trace out, particularly as the species is one which is restricted to hard loamy soils in which it is difficult to dig with a spade. Where the fine roots come into contact with a foreign root they produce a lateral haustorium. In none of the specimens obtained were terminal haustoria found, though these were searched for, as Cannon (8) found them in *Krameria canescens,* (Krameriaceae), an American species, and raised an interesting point in this connection as to the origin of haustoria (see the end of this paper).

The lateral roots may run for a distance of 25 or 30 yards, throwing out smaller roots which form parasitic attachments with foreign roots along their whole length. The range of hosts which one plant may be living on is therefore fairly considerable, both in numbers and in variety. This wide range is shown to an even greater extent by *Nuytsia,* whose underground stem runs for hundreds of yards and whose parasitic attachments may be numbered in thousands along its length.

The depth of these roots in *Fusanus spicatus* is generally not great. As a rule it is about eight inches. They, therefore, might be expected to show some attack on herbs and small shallow rooting shrubs, but at the time of investigation (November) most of the annual vegetation had died with the approach of summer and the smallest shrubs belonged to such species as *Templetonia sulcata* and had a fairly deep rooting habit. These were found to be attacked.

*"Jam" is *Acacia acuminata* and is so called on account of the strong scent of raspberry jam which characterizes the wood.

Host Plants: Rama Rao, in various papers in the "Indian Forester," has recorded the occurrence of haustoria of *Santalum album* on over a hundred species belonging to widely separated genera and families. Among them is an Australian species, the Blue Gum (*Eucalyptus globulus*). Though this number has not been obtained for the Western Australian Sandalwood, it is not improbable that its range is just as wide. In the Pingelly plantation Mr. C. A. Gardner found them on *Acacia acuminata.* At Burracoppin, near the rabbit-proof fence, I obtained them on *Acacia acuminata, Eucalyptus foecunda* var. *loxophleba* and *Templetonia sulcata.* On the goldfields they are parasitic on *Acacia* spp., *Dodonaea lobulata* and *Eremophila* spp. Self-parasitism is fairly common.

The investigation was carried out on specimens obtained at Burracoppin in November, 1920.

Mode of Parasitism (Fig. 1): The fact that Sandalwood is nearly always found growing in very close proximity with another tree, sometimes so close that the trunks are tightly pressed against one another, is very suggestive of a parasitic habit. It is evident that the foreign tree in such cases is the nurse which has enabled the Sandalwood when young to carry on until its roots were able to reach and form parasitic connections with other plants.

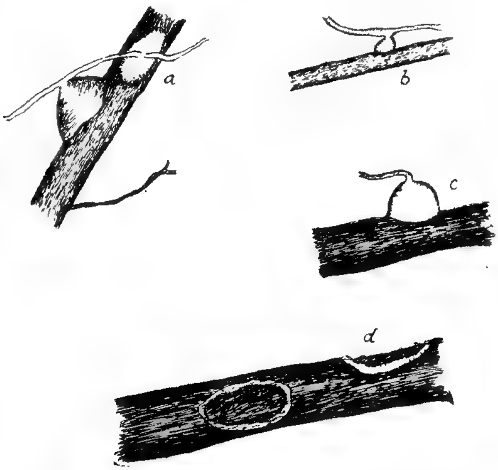

Fig. 1—*Fusanus spicatus*: *a*, haustoria attached to root of *Acacia acuminata*; *b*, young haustorium; *c*, old haustorium with distal portion of parent root shrivelled, leaving an apparently terminal haustorium; *d*, scars on a root of *Acacia acuminata* produced by haustoria which have died and rotted away. (All half natural size.)

The type of haustorium is similar to that of *Santalum*. It arises laterally on a root in contact with another root, either foreign or of the same species. At first it consists of a parenchymatous outgrowth which rapidly enlarges forming a club-shaped organ. The cells in contact with the host have a marked power of destroying and absorbing its tissues, even the outer cork layers. The absorptive cells are rather smaller than the cells of the cortex of the upper part of the haustorium and divide rapidly, pushing in and absorbing the tissues of the cork, cortex, and phloem and even some of the incompletely lignified xylem elements. When the wood is reached the "sinker," as the invading tongue of tissue might be termed from analogy with the absorptive organ of *Viscum* and other Loranthaceae, does not push in any further, but spreads laterally pushing aside the cortex to a certain extent as its margins grow. The cells of the upper part of the haustorium (the part external to the host root) have meantime been dividing and produced a cap-like structure. The whole appearance is like that of a mushroom, the pileus-like part being external to the root and in close contact with it, while the sinker corresponds with the stalk. The inner cells of the external cap have very little power of absorbing the cork layers of the host root with which they are in contact and their function is mainly protective to the sinker, though in *Leptomeria preissiana* they act later as a place for the deposit of waste materials as will be shown later.

The meristematic layer in the young haustorium gives rise to the vascular tissue of the haustorium. This consists of a layer of phloeotracheides in the shape of a Florence flask, often appearing as if it had been flattened laterally. The cells inside this are parenchymatous. The neck of the flask is in contact with the host wood and opens out at this point. The bottom of the flask is connected by a short strand of vascular tissue through the neck to the root. Its tracheides possess bordered pits which are absent in the phloeotracheides. The phloeotracheides in a transverse section are seen not to be in a continuous layer round the parenchyma but to be grouped into bundles. The appearance under low magnification is like that of a young dicotyledonous stem with a number of bundles, but under higher magnification and in longitudinal section it is found that they differ in absence of phloem and in structure of the phloeotracheides themselves.

The host root continues to grow after the haustorial invasion and a callus is formed round the point of entry. This becomes lignified so that in time the bottom end of the sinker is surrounded by wood. The haustoria have only a limited functional existence, the period apparently being about one year. Death and decay occur at the end of this time and a scar, the size varying

with the size of the haustorium, remains. This in time may heal over.

The haustoria are conical and vary up to about three quarters of an inch along their major diameter. They are generally elliptical in section. This is due to the fact that when they have reached the wood, up to which time they are circular in section, further growth in thickness takes place along the line of least resistance, i.e., along the length of the root.

They are produced in large numbers but generally appear to cause little harm to the host, except in the case of a young tree which may be killed by the attack.

These observations indicate that *Fusanus spicatus* is an obligate parasite with a wide range of hosts, and that its haustoria are produced in great numbers, but have only a limited functional existence.

PARASITISM OF FUSANUS ACUMINATUS. R.Br.

Fusanus acuminatus. R.Br., the Quandong, is a small tree attaining a height of about 30 feet. Alternative vernacular names are the Native Peach or the Native Plum, and are in allusion to the fruit which has a red, succulent, edible epicarp with a pleasant acid flavour. Unlike *F. spicatus,* it does not possess a wood of any commercial value (except as an adulterant for consignments of that species, the two woods having a similar appearance) so that it has not been cut out in the forests to any extent. It possesses a very wide range. It is recorded from the Eastern States and in Western Australia is found in similar localities to the Sandalwood, but extends further into the districts of heavier rainfall. Early collectors obtained it from the Kalgan to the Swan and Murchison Rivers, areas in which it is still plentiful.

Like other Santalaceae it does not occur in pure formations, but is always scattered amongst other species. It is frequently found growing close up against a tree of another species, as is the Sandalwood, but is just as often in the open, yards away from another tree. The broad leaf and this apparent isolation, therefore, pointed to a possibility of the quandong being autotrophic.

The investigation was carried out at Merredin in a Gimlet Gum (*Eucalyptus salubris*) forest about six miles from the township, in November, 1920.

Root System: Any doubts as to the possibility of semi-parasitism of the Quandong were removed by digging down and following out the roots. These were found to produce lateral haustoria of a large size and in considerable numbers.

There is a fairly deep taproot as in the Sandalwood, and the lateral roots are very long and extend distances varying up to about twenty yards. It is therefore evident that in cases of apparent isolation of a tree the root may still be long and give rise to haustoria at some considerable distance.

The roots vary in size down to about quarter of a line diameter, the smaller ones being smooth and very pale. There is the typical absence of root hairs common to root-parasitic species. In contact with a foreign root a lateral haustorium of the sandalwood type is produced. Self-parasitism is fairly common.

The haustorium is of the same size and shape as in *F. spicatus* and similar in structure.

Host Plants: The host plants on which haustoria of the Quandong were found were *Templetonia sulcata, Acacia acuminata,* and *Eucalyptus foecunda* var. *loxophleba.* These were the only plants close to the trees examined, but in other districts where the Quandong grows they are absent and other hosts should be found. The former two host plants were growing close by the Quandong. Only one specimen showing parasitism on *Eucalyptus foecunda* var. *loxophleba* was found and this was on a long lateral root which was running right under the parasite. It is probable that this root with its lateral branches had been the nurse of the Quandong in its early life.

If, as is probably the case, *Fusanus acuminatus* is an obligate parasite, it must have a very wide range of hosts. At Woodman's Point it is growing amongst a fairly pure stand of *Callitris robusta,* the Native Cypress. In the garden of Forrest House, Perth, there are two trees the only possible host of which is *Pinus pinea,* the Stone Pine, which is four or five yards distant.

THE GENUS LEPTOMERIA.

This genus is limited to Australia, and contains fifteen species, eleven of which are West Australian. *Leptomeria pachyclada.* Diels (in Diels u. Pritzel, Fram. Phyt. Aust. Occ., 178) is the only species described since Bentham's time. The western species do not extend to the Eastern States and vice versa. The plants of the genus are shrubs of a typical Santalaceous appearance with numerous slender leafless branches. The examination of two of these western species, *L. priessiana.* DC., and *L. spinosa.* DC., shows that they are root parasites, but that their modes of attack are very different. Probably all other species have the same habit, but up to the present they have not been examined because of the remoteness from Perth of the localities where they flourish.

PARASITISM OF LEPTOMERIA PREISSIANA. DC.

Leptomeria preissiana is a leafless shrub with slender erect branches, attaining a height of about three feet. It was originally described from Swan River specimens collected by Oldfield and Preiss. Since that time its range has been found to extend far into the Coolgardie district, Diels having collected it at Karalee, a district 268 miles east of Perth on the Great Western Railway. His specimens were similar to the Swan River forms. It is also found on Garden Island. This investigation of its parasitism was carried out on plants growing on the sand plain three miles south of Westonia on the road to Carrabin. This also is in the Coolgardie district, but the typical Avon district forms have not all disappeared with the decreasing rainfall. The species was undoubtedly *Leptomeria preissiana,* but the little lateral racemes of flowers were more terminal than in the Swan River forms.

In the loose, light soil of the Westonia sand plain the plant develops a profusely branched and widely spreading root system. In this it resembles most of the other shrubs associated with it. The texture of the soil is largely responsible, but not wholly Other plants on the heavier loam adjacent are more deep-rooted and their roots do not ramify to the same extent as do those of their neighbours in the sand. Those of *Leptomeria preissiana* are more numerous and more branched; there is a fairly well-developed branched taproot of about three quarters of an inch diameter and the lateral roots vary down to about a quarter of a line diameter. They are pale and fleshy and with the almost total absence of root hairs characteristic of other root parasites. In contact with other roots these small roots give rise to a lateral haustorium. This haustorium in several hundred specimens obtained was never terminal, though in some cases through withering of the distal part of the root it appeared so. It is of the *Fusanus* and *Santalum* type but shows some interesting points not found in these genera.

Owing to the profuseness of the branching of the root system and the sparseness of the surrounding vegetation on the sand plain, it is natural that in their searching after a host the haustoriogenetic roots should come into contact with others of their own kind more frequently than with roots of other species. This is actually the case. Though the haustoria are common on *Acacia signata,* the Wodgil, in thickets of which the plants were growing, by far the greater number were found on the plant's own roots. These are the most convenient to examine, as the *Leptomeria* roots are softer and easier to section than those of *Acacia,* and because of their smooth bark are much neater specimens for preservation. Sections were cut of haustoria attacking both their own roots and those of *Acacia* and the modes of attack found to be similar in all details.

Host Plants: Haustoria were found on *Acacia signata,* the Wodgil; *Duboisia hopwoodii,* the Pituri of the natives (which is here at about its western limit), and commonly on roots of *Leptomeria* itself, as mentioned above.

Mode of Parasitism (Fig. 2): The roots from which the haustoria arise are generally about a quarter of a line in diameter. They are white and fleshy and as in the case of the sandalwood the greater part of the area in section is occupied by large-celled cortical tissue, the vascular tissue occupying a small central strand. On this account they are rather brittle, but not nearly so difficult to remove from the ground on this account as are those of *Nuytsia floribunda.* When they come in contact with a host root a haustorium is formed laterally. This at first consists of a clavate mass of parenchymatous tissue with a meristematic zone continuous with the vascular elements of the root. The cork

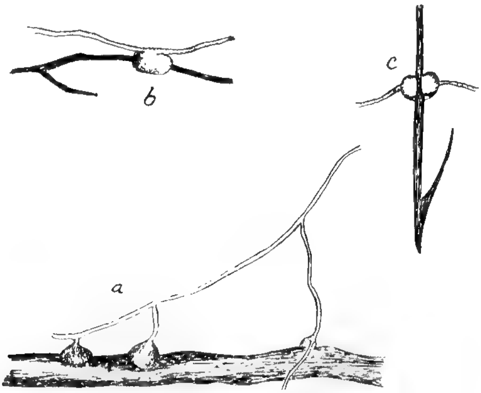

Fig. 2 Haustoria of *Leptomeria preissiana*: *a,* typical form; *b* and *c,* examples where the cap has wrapped round the small host roots to produce a structure somewhat similar in outward appearance to the haustoriogen of *Nuytsia floribunda.*

cells of the host are first attacked and absorbed. The absorptive cells are smaller than those of the upper part of the young haustorium. Subsequent development is similar to that found in *Fusanus spicatus* and in *Fusanus acuminatus.*

The phloeotracheides are reticulately thickened and as in *Exocarpus* differ from the tracheides of the neck in absence of circular bordered pits. They are accompanied by unthickened protoplasmic nucleated cells of similar size and shape which are scattered amongst them. The inner part of the "nucleus" of the haustorium is occupied by parenchymatous cells.

Morphology of the Haustoria of Leptomeria preissiana: In the beginning of the attack the haustorium is a small clavate body of little over half a line in diameter and consisting chiefly of parenchymatous tissue. This rapidly enlarges as the sucker penetrates the cork and the underlying tissues and the size it attains depends mainly on the size of the root attacked.

A small root, say a line in diameter, may be almost completely wrapped round by the cap portion of the haustorium in which case the appearance is very like the haustoriogen of *Nuytsia floribunda* (9). In *Nuytsia* no tongue of vascular tissue is intruded into the host root. The absorbing organ forms a complete circle round the root it is attacking and on the inside by rapid division of the cortical cells small tongues of parenchymatous assimilatory tissue are developed. *Leptomeria* differs in having a distinct sinker with vascular tissue, and the wrapping round of the cap portion of the haustoria on small roots does not result in a fusion on the far side and production of a ring. The ring in *Nuytsia* has been termed the haustoriogen on account of the production of these assimilatory tongues on its inner surface. These are not found on the inner side of the cap of *Leptomeria preissiana.*

If the host root is of sufficient size the *Leptomeria* haustorium will attain a diameter of about one third of an inch when fully developed. It may be circular or elliptical when looked at in face view, and is conical when looked at from the side and is up to one third of an inch in height.

Whether the haustorial cap is circular or elliptical in face view depends on the amount of penetration of the sinker. Up to the time that this reaches the wood, it is circular. When, however, it reaches this and starts to spread out it finds that the path of least resistance is along the vertical length of the host root and it commences to grow in this direction. The cap grows at the same time in the same direction and becomes elliptical in section.

The haustoria are produced in great numbers. Each plant examined had produced several hundred and probably the number ran into thousands. The amount of food material obtained must be very considerable, and may account for the luxuriant development of flowers.

Developments of the Haustoria after attaining maturity: When the haustoria have attained this size growth ceases. The host root continues to grow and the edges of the sinker become embedded in newly formed wood. Callus tissue is produced in the inner cortex, and wood elements appear here also. The cap begins to be forced outwards, and the appearance is as if the

plant is endeavouring to strangle the invading tissue. The haustorium then commences to die. Its cortical cells are now used as a place for the deposition of waste products. Calcium oxalate, which occurs in other parts of the plant to a very limited extent, is deposited in large sphaero-crystals. The connecting root shrivels, dries, and turns black, and the cortical tissues shrivel and disintegrate. Finally the only evidence of attack is a deep scar on the host root with the remains of the vascular tissue of the haustorium still protruding. The scar generally heals up in time leaving a longitudinal depression varying in size according to the size of the original injury.

Haustoria are formed at all times of the year. On a single root several may sometimes be found in all stages from the small parenchymatous outgrowth up to the withering haustorium of a third of an inch diameter. Their limited functional existence is, therefore, not dependent on the seasons.

PARASITISM OF LEPTOMERIA SPINOSA. DC.

Leptomeria spinosa is a much branched rigid but somewhat decumbent shrub of about two feet in height, and like the other members of its genus leafless at the time of flowering (September to November). Like *Leptomeria preissiana* it has a wide range, Drumond, Preiss, Oldfield, Maxwell and others having collected it in the Darling, Avon, Stirling, and Warren districts. The plants on which this investigation was carried out were growing on a sand plain* near Yoting in the Avon district. (Yoting is an agricultural district 135 miles from Perth by railway, on the York to Merredin line.)

Root System: The plant develops a well branched root system of a type similar to that of *L. preissiana.* There are the typical pale, somewhat fleshy roots with the almost complete absence of root hairs. These ramify through the loose sand, but unlike the other species, when they strike a foreign root do not always produce haustoria. The only species which they were found to be attacking was *Eremaea pilosa,* a low Myrtaceous shrub fairly widely distributed through the dry areas. The first plants of *Leptomeria spinosa* examined were growing amongst a thicket of native cypress (*Actinostrobus acuminatus*) with here and there a shrub of the grotesque-fruited *Hakea platysperma* and other species. The roots of these were examined but in no case were

* This sand plain was characterized by a very glaucous form of *Gastrolobium spinosum* with thick entire leaves. Transitions of the normal form with rather thin leaves with lateral spines were found so that it could not be regarded as a distinct variety.

haustoria found. On *Eremaea*, however, they were exceedingly numerous. The species was not very common on this sand plain and all the plants observed were growing close to the base of *Eremaea* shrubs. Self-parasitism was not observed. In *L. preissiana* it was the most noticeable characteristic. It is therefore evident that *Leptomeria spinosa* possesses a higher degree of specialisation in its selection of a host than its relative and the other species examined. It probably has other hosts as it has a very wide range, though *Eremaea* and other allied Myrtaceae have the same range, but does not share in the apparent indifference to the nature of the host root shown by the Loranthaceous *Nuytsia* and (to a lesser extent) *Fusanus* and *Exocarpus*.

Mode of Parasitism: The roots vary in diameter down to about a quarter of a line in diameter. They are ultimately more slender than those of *L. preissiana*. When one of these small roots comes into contact with a host root it applies itself closely to it. What appears at first sight to be a terminal haustorium is formed, but close examination shows that it is really lateral but very close to the tip of the root. The tip grows on and the root creeps along the host root producing small haustoria at intervals of about one line under ordinary circumstances (Fig. 5). The haustoria are not produced on the same side of the root. Some are produced on the side in contact with the host root, others on the sides, and others on the side remote from the point of contact. These latter, however, turn round and apply themselves to the host in the ordinary way. The only difference is in the length of the neck.

One root creeping along may produce thirty or forty haustoria. Though in close contact there is no fusion between the cells of the host and parasitic roots. This can be shown where a root has crept along and worked its way into a fissure in the bark of the host root. It forces its way through the living bark but emerges without having produced more than a mechanical piercing. *Cuperus rotundus*, the Nut Grass, one of the native Cyperaceae, which is a common weed of cultivation, does this and at Spearwood (a few miles south of Fremantle) often damages onions and potatoes in the same way with its creeping rhizomes. All the parasitism of *Leptomeria spinosa* is done by the haustoria and never by the root itself.

Morphology and Histology of the Haustoria: The haustoria as in *Leptomeria preissiana* are lateral. They first appear as a parenchymatous outgrowth and if on the side of the root in contact with the root, they grow downwards absorbing the cork cells and penetrating the cortex. The shape is similar to that of the other species. If they are formed on the other side of the

root the length of the neck is much greater and the shape of the whole clavate instead of conical. From a meristem the vascular system of phloeotracheides is produced and is of the shape of an inverted flask connected with the tracheides of the neck at the bottom and having the top near the region where the end of the haustorium is in contact with the cortical cells of the host. The ends of the phloeotracheides are not in contact with the cells of the foreign root; the actual attack is carried out by unlignified parenchyma cells.

The haustorium does not penetrate as far as the wood. In the great majority of cases it does not go far into the cortex, and

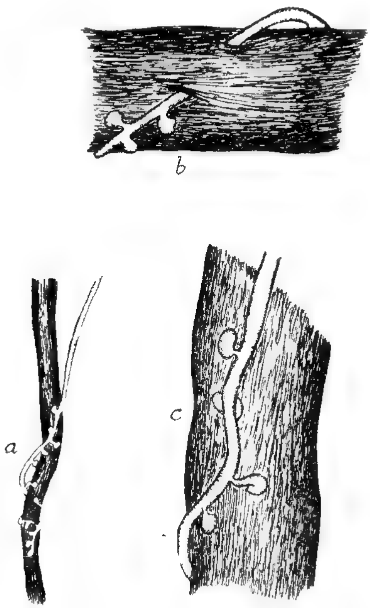

Fig. 3—Haustoria of *Leptomeria spinosa*: *a*, half natural size; *b*, mechanical piercing of the bark of *Eremaea pilosa* by root of *L. spinosa*, enlarged; *c*, haustoria arising from a root of *L. spinosa*, enlarged.

the root can be removed with the haustoria intact by pulling it gently away from the host. The same factors which tend to make the haustorium of *L. preissiana* elliptical in section are, therefore, not operating and the section in this species is circular. The maximum size is about a line and a half in diameter and two lines long.

The number produced is very great and amounts to several thousands for each plant. In November, when they were collected,

all stages of development were found, which would seem to show that they are formed all the year round.

Their functional existence is not limited except by the life of the root. Examination of several hundred showed that only where the parent root had died off had the haustoria died.

The fact that plants belonging to this species were not common in spite of the abundant production of seed, and that in all the cases examined they were parasitising the same species of host indicates that not only is *Leptomeria spinosa* an obligate parasite, but that its choice of hosts is very restricted.

THE GENUS CHORETRUM.

The genus *Choretrum* is limited to Australia, and contains five species, three of which are found in Western Australia. These are *C. glomeratum.* R.Br., *C. pendulum* Tovey and Morris, and *C. lateriflorum.* R.Br. The plants of the genus are shrubs with slender rigid branches with the leaves all reduced to minute scales, which are usually deciduous.

Parasitism of Choretrum lateriflorum. R. Br.:

Choretrum lateriflorum is a shrub of two or three feet with erect broom-like branches. It occurs round King George's Sound in the Warren district in Western Australia and has a wide range in Victoria and New South Wales. At Denmark it grows in the Karri (*Eucalyptus diversicolor*) forest in hilly country. At Albany it grows on sand plain amongst Jarrah and Sheoke, and at Redmond in low lying, sandy, swamp country. The investigation of its parasitism was carried out at Redmond, near Albany, in March, 1921.

Host Plants: Haustorial attachments were found on *Casuarina fraseriana,* one of the sheokes, and also on a species of *Pimelea* in large numbers. Self parasitism is also common. Other roots not belonging to these species were found attacked but it was not certain which plants they belonged to.

Root System: *Choretrum lateriflorum* has a well developed lateral root system, the roots being reddish brown and the smaller rootlets white. The small haustorium bearing rootlets are extremely slender and fragile, some being about the diameter of a hair, others varying up to about an eighth of a line. When they come into contact with a root they creep along it giving rise to lateral haustoria along their length.

The Haustoria (Fig. 4): The haustoria are very minute and either discoid or conical in shape. When full grown they do

not exceed about one third of a line in diameter at the point of attachment, and most of them are only half this size. Because of their small size and the minuteness of the root on which they are borne it is not to be expected that they will penetrate far into the host. In section it is found that though their attack is well marked they do not go far into the cortex and do not reach the wood. The actual task of attacking and dissolving the cells of the foreign root is undertaken by parenchymatous cells at the tip, the phloeotracheides not being in contact with the host tissue. No small roots were found attacked by *Choretrum* haustoria. It is probable in such a case that the sinker would penetrate as far as the wood, as the structure of the haustorium attacking a large root is very similar to that of the haustoria of *Leptomeria preissiana* and *Fusanus* in their young stages.

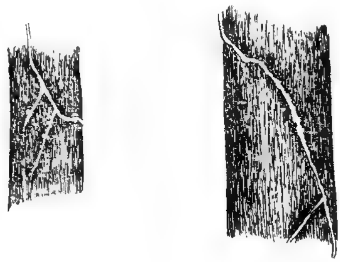

Fig. 4—Haustoria of *Choretrum lateriflorum*, half natural size.

Haustoria are probably formed at all periods of the year. These were collected in March, at the end of a long dry summer, and some were within about four inches of the surface of the ground. There was no evidence of limited functional existence as in *Fusanus* and *Leptomeria preissiana*.

In a few cases they appeared terminal but under the microscope it was clear that they were lateral but that the root had died back, giving them a terminal appearance. In other examples the hair-like rootlet of *Choretrum* crept along the host root and to the naked eye appeared as if it were fusing with it along its lower surface, i.e., as if the cortical cells were capable of absorbing the cork layer. On sectioning, however, it was found that the points of contact represented immature haustoria.

THE GENUS EXOCARPUS.

Eight species of *Exocarpus* are recorded from Australia, and three of these are known with certainty to occur in extra-tropical Western Australia. These are *E. odorata* (restricted to this State),

E. aphylla, and *E. spartea*.. A fourth species common in the Eastern States is recorded from the evidence of a doubtful specimen of *E. cupressiformis* from Wilson's Inlet collected by Oldfield. *E. latifolia* from the north of the State, has been found by Gardner (10) to be parasitic on *Petalostigma*, *Canthium*, *Terminalia*, and *Callitris intratropica*; its haustoria are described as slug-shaped, about 2cm. long and 1.5 cm. wide, thick and fleshy, numerous.

Parasitism of Exocarpus aphylla:

Exocarpus aphylla, a shrub of 3 to 8 feet, occurs in the Eremaea and is easily distinguished amongst the other vegetation by its leafless, hard, thorn-like branches. It prefers loam soil and on the wheat belt is found in Salmon Gum (*Eucalyptus salmonophloia*) and Gimlet Gum (*Eucalyptus salubris*) forests. It has a deep root system and the stony loam in which it grows renders it very difficult to investigate its root system. Only one plant was examined. This was at Burracoppin, a district forty miles east of Merredin and near the edge of the wheat belt.

One shrivelled haustorium was found on an *Acacia* root and on the same root were scars, the records of an old attack from which the plant had recovered. This haustorium was too withered to section, but was of the same type as those produced by *Leptomeria spinosa*, *Fusanus*, *Santalum*, and other genera. It measured about one quarter of an inch in diameter at the point of contact with the host root, so that it compares in size with those produced by *E. spartea*, described below. Those of *E. cupressiformis*, of which a full account is given in Dr. Benson's paper, are very minute and compare with those of *Choretrum lateriflorum* R.Br., which are also described above.

The habit of *Exocarpus aphylla* is suggestive of parasitism. The leafless branches, its insignificant flowers, and the fact that it grows up close to other plants (sometimes appearing to grow out of the centre of another shrub) point to this. Unfortunately the time available to investigate it was very short. The investigation was carried out late in the afternoon on plants about forty miles from Merredin, which had to be reached by nightfall, and the cement-like nature of the soil and the deep rooting habits combined against the obtaining of more evidence.

Exocarpus aphylla is, therefore, parasitic on at least one host, and its haustoria are of the *Santalum* type. Further investigation is necessary to determine whether, like *Leptomeria spinosa*, it is restricted in its choice of hosts, whether it is an obligatory parasite, whether it ever has self-parasitic habits, and if haustoria are produced at any particular season or throughout the year. The shrivelled haustorium obtained was in the hard-baked dry soil

about six inches below the surface. Here, of course, none would be formed in summer, so that their production would be seasonal in the upper layers. Down below, however, where moisture is available throughout the year, it is possible that they are being formed at all seasons.

Parasitism of Exocarpus spartea. R. Br.:

Exocarpus spartea R.Br., like *E. Aphylla,* has a wide range through the Eastern States, as well as through the West. It is very variable in habit. Specimens obtained from Geraldton in November, 1919, were from a low shrub of about 4 feet in height, similar to the form found round Perth. This is the form found in sandy soil. In the loam at Northam and Greenhills the species takes the form of a tall shrub, or small tree, of about 15 feet with slender rather pendulous branches. These were flowering in November, 1920. The Geraldton plants were in an advanced stage of fruiting at this time, but this is natural as the season becomes later as you go south.

The species is recorded from King George's Sound in the south to the Murchison River in the north. In the east Gardner has collected it at Wyalkatchem, Kellerberrin, Kondinin and Esperance. The investigation of its parasitism was carried out at Greenhills in November, 1920. Here it was growing amongst York Gum (*Eucalyptus loxophleba*) and Jam (*Acacia acuminata*), the two species that comprise the characteristic arborescent vegetation of the Avon district. In April, 1921, plants were examined at Nedlands on the Swan River, a few miles from Perth. Here they were growing in sand in an open Jarrah (*Eucalyptus marginata*) forest, with a number of small shrubs round their bases.

Host Plants: The soil at Greenhills was a red, sandy loam and supported a vegetation consisting of herbaceous Compositae (*Helichrysum* spp., *Brachycome* spp. etc.), a few grasses, and the two trees already mentioned. Here and there were a few sheokes (*Casuarina glauca*) and Flooded Gums (*Eucalyptus rudis*) but no Exocarpus trees were growing near them. Haustoria were obtained at a depth of about eight inches on both *Eucalyptus loxophleba* and *Acacia acuminata.*

At Nedlands the flora was quite different. There were over a hundred different species of trees and shrubs growing in the area. Where the *Exocarpus* shrubs were growing were *Gompholobium tomentosum, Casuarina humilis, Banksia menziesii,* and *Banksia ilicifolia.* Parasitic attachments were found on all these species, and self-parasitism was common.

Root System: The roots of *Exocarpus spartea* are similar to those of the other species described. They are reddish-brown in colour, the smaller ones being pale and whitish, with a characteristic lack of root hairs. There is a branched taproot with a large number of ramifying shallowly placed lateral roots. At Greenhills, in the loam, these came to within six inches of the surface; in the Nedlands sand they were about three inches down.

The Haustorium (Fig. 5): The presence of another root is not necessary for the production of haustoria, though they are formed more abundantly if one is there. They arise laterally as small parenchymatous nodules which enlarge by rapid division of an apical meristem. Where no host root is present they ultimately reach a length of about two lines and a breadth of about one line at the broadest part. The shape is clavate, the neck end being the narrower. The structure follows the same lines as in *Leptomeria spinosa.* The vascular tissue is in the shape of a flask but the part corresponding to the neck of the flask is much longer than in the case of any of the other species examined and is often much broader. Its phloeotracheides end in the cortical tissue of the tip, the actual attack being carried out by parenchyma cells. This vascular sheath, like the other species, has its phloeotracheides grouped into bundles similar to the arrangement in a young stem, but differing in their microscopic structure. The bundles are more widely separated, however, than in the other species and in a longitudinal section one side of the sheath may be missing owing to the section having passed between two of them instead of through them. In haustoria not connected with a host root the vascular sheath may not be flask-shaped, but may round parallel with the outer surface of the haustorium.

When the young haustorium is formed in contact with another root, either one of its own species or a foreign one, its mode of attack is similar to that of *Leptomeria spinosa,* but is much more feeble. If it is in close contact it may penetrate into the cortical tissues dissolving the cork layer and the outer cortical layers. The host wood is not reached. All the collecting of food materials from the host cortex is done by parenchymatous cells. If the haustorium is not in close contact with the root, there may be no piercing of the tissue at all. The haustorium may run along the root like an ordinary root, and the only fusion take place along its sides and not at the tip. Such a fusion is very weak and the haustorium readily comes away at a very light pull.

An interesting case was where a haustorium had come into contact with the wood of a root of *Acacia acuminata* which was

exposed through a splitting of the bark. The haustorium had run along between the wood and bark, fusing with the latter, but showing no signs of attempting to attack the wood (Fig. 5 *d* and *e*).

Fig. 5—Haustoria of *Exocarpus spartea*: *a*, root, half natural size, producing haustoria in contact with a root of *Gompholobium tomentosum*; *b*, an *Exocarpus spartea* root with one haustorium arising independently of a host, the other attacking its parent root; *c*, independently formed haustoria showing their lateral nature; *d*, a haustorium formed in a fissure in the bark and adhering to the bark on the lower side; *e*, same haustorium raised to show that it did not attack the wood of the host.

GENERAL FEATURES OF PARASITISM OF THE SANTALACEAE.

Self Parasitism: Self-parasitism is common in five of the seven species examined, and it is not improbable that the other two possess the same property. One would not expect it to be

a very successful operation, for a necessary condition for parasitism is that the parasite should have a higher osmotic power than its host. Thus McDougal (11) in the artificial production of parasitic conditions was able to make *Cissus* with an osmotic activity of 11.34 atmospheres maintain itself on *Opuntia blakeana* at 8.88 atmospheres. The osmotic pressures of the cells of the haustorium and of the root cells of the same plant might be expected to be so close that attempts at self-parasitism would be unsuccessful. The work of Hill (12) and others, however, indicate that the success with which such an attempt is met with in the cases described may be accounted for by differentiation in osmotic pressure in the haustorium. Working on the root hairs of salt marsh plants Hill showed that in contact with a higher concentration of solution than in their own cells they automatically increased their osmotic activity.

The Haustoria: Gautier has shown in the case of *Melampyrum pratense*, and Barber in the case of *Santalum album*, that the haustoria always arise laterally. Goebel, on the strength of their lateral nature in the known cases, advanced the theory that they were distinct organs, and did not arise as modifications of roots. Cannon, however, in his work on *Kremeria canescens* (Krameriaceae) showed that though in this species lateral haustoria were formed they were also produced terminally as modified root tips, and are, therefore, not new organs. "In older plants, however, the haustoria may be new organs, but this is not proved."

In none of the seven species described above were there any terminal haustoria. In a few cases in *Exocarpus spartea* (Fig. 7) and in *Leptomeria preissiana*, what appeared at first sight to be terminal organs were found, but if the real lateral nature could not be discerned by examination with a lens, it was found on sectioning and examination under the microscope. In *Fusanus spicatus*, *F. acuminatus*, *Leptomeria preissiana*, *L. spinosa*, and *Exocarpus spartea*, old haustoria were met with having a terminal appearance, but this was due to the root having died back to the point where the haustorium had arisen.

The phenomenon noticed in *Exocarpus spartea* (Fig. 7) the fact that the phloeotracheide sheath of a haustorium not in contact with a host runs parallel with the outer surface of the organ, seems to show that the flask shape of this sheath is directly due to the entry into the host. When the haustorium is young the first formed phloeotracheides are parallel to the surface (that is at the "bottom of the flask"). When the host bark has been pierced, however, the vascular elements are produced from a meristem following behind this first point of entry and the result is a narrowing to the flask shape.

The nature of the haustoria does not seem to be a generic character. Those of *Leptomeria preissiana* are similar in structure to those of the two species of *Fusanus,* differing only in size. *Leptomeria spinosa* differs in quite a marked manner in size and appearance, and do not penetrate to the same extent as the other member of the genus. They resemble more those of *Choretrum lateriflorum* and *Exocarpus spartea,* the main differences of which lie in their size. This *Exocarpus* differs from *E. cupressiformis,* as described by Dr. Benson, in that its haustoria, though attaining a considerable size do not penetrate further than the outer cortical layers of the host. Thus it appears that the general type is the same throughout the genera, but that though it varies greatly in the different species the differences are not generic.

SUMMARY.

1. The seven Santalaceous species examined, *Fusanus spicatus, F. acuminatus, Leptomeria preissiana, L. spinosa, Choretrum lateriflorum, Exocarpus aphylla,* and *E. spartea* are all root parasitic, but differ in mode of attack.

2. In the first three species there is contact between the vascular system of the haustorium and that of the host root. In the others (except *Exocarpus aphylla,* of which the material obtained was not sufficient for a thorough examination), the attack was carried out by parenchymatous cells which only penetrated into the cortex; the phloeotracheides were not in contact with host tissue.

3. *Fusanus spicatus* is an obligate parasite and from the large numbers of haustoria found in all the plants of other species examined, they probably share this property.

4. *Leptomeria spinosa* shows discrimination in choice of a host. At Yoting it was only found on *Eremaea pilosa.* The other species are more cosmopolitan in taste.

5. In *Exocarpus spartea* the presence of a host plant is not a necessary preliminary to haustorium formation.

6. The haustoria in all cases are lateral and appear to be distinct organs and not, as is sometimes the case with *Krameria,* modified root tips.

7. In *Leptomeria spinosa* the roots sometimes pierce the outer cortical layers, but there is no fusion with them by the ordinary roots. All absorption is done by haustoria.

8. The flask shape of the vascular sheath of the haustoria

of these species is ascribed to the method of attack on host plants. This is not produced in haustoria of *Exocarpus spartea* formed independently of a host root.

9. The phloeotracheides in these species occur in bundles round an inner parenchymatous core, and not in a continuous layer, as in *Exocarpus cupressiformis,* nor in two bundles as in *Thesium.*

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Science and Industry. By Professor **A. D. Ross**, M.A., D.Sc., F.R.S.E.

(Presidential Address. *Read* July 14, 1925. *Published* August 15, 1925).

On 30th June last there occurred the centenary of the birth of Baron Sir Ferdinand von Mueller. The event is of special interest to us as our Royal Society has gradually developed from the Mueller Botanical Society a society named after the distinguished botanist. Von Mueller was born at Rostock and received his education at Kiel. From 1840 to 1847 his time was spent in the investigation of the flora of Schleswig-Holstein. Thereafter he emigrated to Australia owing to hereditary phthisis, both of his parents having died through that disease. For some four years he acted as a druggist's assistant in Adelaide and then secured appointment as Government Botanist. His inclusion as botanist in Gregory's Expedition of 1855-1856 across Northern Australia brought him into prominence, and from 1857 to 1873 he held office as Director of the Melbourne Botanic Garden. Von Mueller was a prolific writer. He had at one time contemplated the issue of a general Flora of Australia, but at the suggestion of Bentham sent his notes on this subject to Kew. His more utilitarian works included illustrated monographs on the *Eucalyptus* and *Acacia*, and his *Census of Australian Plants* was an important contribution to natural science. After holding many prominent offices in scientific societies, including the Presidentship of the Australasian Association for the Advancement of Science, Von Mueller died in Melbourne on 9th October, 1896. Before his death he spent a period studying the flora in the southern part of our State. So it came about that on the formation of a botanical society in Western Australia, in July, 1897, it was given the name of the Mueller Botanical Society. The gradual broadening of its sphere of activity to that which our Royal Society now claims would have been impossible but for the rapid multiplication of specialised societies. To maintain an effective central or co-ordinating society puts a heavy responsibility upon the members, and, despite anything they might attempt, little could be accomplished but for the hearty support of these specialised societies. Therefore it is to-night my pleasant duty to welcome to our meeting delegates from the various scientific, industrial and commercial organisations of Western Australia.

As I complete to-night a two year's occupancy of the presidential chair of this Society, my mind naturally reverts to the winter of 1917, when I was similarly called upon to deliver an address as your retiring President. On that occasion I took as my theme "The State and Science." On glancing over that address a few weeks ago I was struck by the singular appropriateness of the subject even at the present time. Then we were in the midst of the greatest war our world had ever known, and the combatant nations were striving to organise so that they might throw all their weight into the conflict. We thus came to realise the existence of many deficiencies in our boasted civilisation, in our industrial methods and in our commercial enterprises. The time was opportune for reforms. But the exigencies of the situation demanded that it must for the moment be a reorganisation on a war-time basis, and we were left to hope that on the cessation of hostilities we would without delay adapt our reforms so as to make ourselves an efficient nation in the times of peace. In 1917 I said, "A new national spirit has been aroused in the British nation by the war . . . But, if we are to recover and improve our position at the end of the war, that national spirit must be maintained. Unless every man and woman comes to know and feel that industry, agriculture, commerce, shipping and credit are national concerns, and that education is a potent means for the promotion of these objects among others, we shall assuredly fail in the great effort of national recuperation. In plain words, our great firms will not make money, wages will fall, and wage-earners will be out of work."

It was difficult then to realise the turn that events might take. The magnificent performance of Australian troops at Gallipoli and in other theatres of the war, called forth world-wide praise. But it was only towards the end of the conflict that we came to recognise the result of this work of the Australians. An Australian nation had been born. There was no suggestion of any slackening of the bonds of union with the homeland. On the contrary, it was the natural outcome of the growth of a sturdy son of the Mother country. That evolution brought with it recognition of the fact that it was the duty of a youth approaching years of manhood to lean less on parental support. Rather was it a duty to assist the parent by following with some independence in the common pursuit of the same aims and same ideals. Such healthy and commendable independence entails new obligations. During the past few years it has become the duty of Australia to take responsibility for the growth and wise development of her own industries and commerce. Instead of leaning on the home country, rather is it now Australia's duty so to develop her resources that they may be an aid to others of our

race who, immigrating to our shores, seek a new home and steady employment.

In 1917 I stressed the importance of a wise application of science in the development of industry and commerce. Let us look into the position as we find it to-day.

At the outset it will be readily admitted that industries and commercial enterprises to be successful must pay and pay well. The less the financial margin in any undertaking, the less must necessarily be the allocation of funds for those of its agencies which operate for the cheapening and improvement of its technical designs and processes; and, unless those agencies are properly developed and take an important place in an organisation, technical efficiency must suffer, and suffer severely.

And what of science? "Applied science," said Sir Michael Sadler, "'was nobly defined in the charter granted in 1828 to the Institution of Civil Engineers as 'The art of directing the great sources of power in nature for the use and convenience of man.' Applied science derives most of its strength from pure science, pure science a part (though only a part) of its vindication and encouragement from applied. The difference between them is less one of subject-matter than of motive. Either isolated from the other is weakened through lack of contact with the characteristic virtues of its opposite. Both may form part of the life-work of a single investigator."

From the position thus stated so clearly by Sir Michael Sadler, it is evident that work in so-called pure science may be as helpful in advancing industry as research in so-called applied science. He would indeed be rash who would venture to predict whether a particular research might or might not prove beneficial in its future applications. The application of X-rays to surgical diagnosis and to therapeutics is the direct outcome of inquiries into the fluorescence of certain rare minerals. Broadcasting, in the same way, owes its existence to the mathematical investigations of Kelvin, Maxwell, and others, in electrostatics and in connection with the oscillatory character of certain electric discharges. Every department of science affords innumerable examples of a similar kind.

Further, the history of invention shows clearly that in regard to new processes and new machines most of the important steps have been taken, not by those engaged in the particular art so revolutionised, but by those whom we may call outsiders. Lord Kelvin's many contributions to navigation and to submarine telegraphy are cases in point. It was the investigations of Sadi Carnot into the nature of heat that led ultimately to the development of heat engines. The conception of the regenerator as adding

to the efficiency of heat engines was due to a Scotch clergyman, the Rev. Robert Stirling. So also, on the other hand, we find that where external contact with industry has been least, improvements have come about very slowly. In a lecture on the Textile Industries given in 1923 by Dr. A. E. Oxley, he deplored the fact that while these industries had been one of the great factors in civilisation, they had not sought nor been offered the help which could be obtained from scientists unconnected with the industries. Practical spinners tell us that as a result the principal machines are undeniably inefficient. The most important machine in spinning is the carding machine, yet, despite the improvements introduced by Bourne, Paul, Arkwright, Evan Leigh, and Walsh, the performance is altogether unsatisfactory. In carded yarns there are too many motes and neps, and those in the industries have failed to eliminate these faults. They have to be content with keeping them within reasonable bounds, and so to-day, as an expert in the trade has put it, "whilst the carding machine is indispensable, it is a failure." I venture to think that it is also because of the lack up to recent years of scientific interest in the matter that we are still using cranks in engines whose form from a mechanical point of view is simply grotesque. It is by the outsider coming in and approaching the long-standing problem in an unconventional manner that the solution is generally attained. Here it is where the trained scientist has his great advantage. He has the basic knowledge that guides him in attacking the problem. James Watt's invention of the separate condenser was brought about by his clear and well founded appreciation of its physical function in preventing waste, waste of steam and therefore waste of coal. In his own words, his object was to keep the cylinder as hot as the steam that entered it. So again it was Sir William Bragg's intimate knowledge of the development of X-ray apparatus and of the penetrating power of the shorter wave-lengths that led him on in his applications of these rays in the examination of metal castings, fire-bricks, etc.

It must always be borne in mind that for the efficient application of science in industry there must be full co-operation between the scientist and the industrialist. The practitioners in the art must undoubtedly have the sounder views regarding the limitations imposed by the conditions under which industrial processes can be conducted. It may not be possible, and if possible it may not be wise, materially to change the current of one industry without taking account of the many conditions, external to that industry but bound up with it in the scheme of production, distribution and utilisation, as that scheme is organised through long years of growth and adjustment. Moreover one must not decry the ability of the truly skilled operative. The success of empiricism in industries is suggestive. It is amazing to find how

successful it has often been, and it is one of the most difficult of problems to ascertain how far variations in raw products will permit the substitution of control by measurement for control by judgment. The researcher's functions are undoubtedly complementary to those of the operative. Science should be the leaven of industry; we must not regard it as the lump.

Clearly the ideal method of getting most out of science in an industry is to establish a research man in the works. It is not sufficient for the manufacturer to ask an outside consulting chemist, physicist or engineer to suggest a remedy for some particular trouble. The difficulties that are apparent are generally purely symptomatic and do not form the true problem to be discussed. Only a full acquaintance with the various processes in the work and the scientific basis of these will enable the scientist to get down to the real nature of the trouble and to offer a solution. The research worker must become an integral part of the works staff. He must live with the work, study it in all its parts, and learn to know and judge the personnel of the concern. How otherwise can he hope to assist the management with proposals for sweeping changes and to receive the support of the staff? How else can he know the conditions under which his proposed remedy will be applied? It is thus evident that at the outset the research worker must be given every scope for getting fully acquainted with the new field of his labours. Those in Universities who direct research students are aware that a very great amount of time is taken up in every research in getting to know the field and nature of the inquiry. It is not uncommon for the actual advance to be made in less than a tenth of the whole time given to the subject. Nine-tenths of the time had of necessity to be devoted to gaining acquaintance with the general literature, previous investigations, and the instrumental equipment. In selecting a research man for industrial concerns experience in the same class of technical work is not necessary, and is often a very great hindrance because the individual comes with fixed ideas. A research man from a rival industrial concern is generally the worst choice. A man who knows his science, who has had some experience in research methods, and who possesses energy, imagination and ambition will soon put himself in the position where he can bring his scientific training into play on the industrial problems.

Before leaving this topic let me add that the research man's work is not finished when a plan of manufacture has been evolved. Mass production brings new and frequent matters for careful examination. It is the unavoidable variation in quality of the raw products in mass production that has ruined so many industrial concerns. The business manager who thinks there is no

further need for scientific oversight after a successful article has been evolved, is inviting disaster. To dispense with the technical adviser is without doubt a penny wise and pound foolish policy.

Having thus discussed the general question of the application of science in industry and commerce, let us return to a consideration of our young Australian nation and of how science is here to foster and to assist in the development of industries. Four main lines of action at once suggest themselves:

(i) Industrial concerns may each individually take such steps towards the application of science in their respective businesses as will result in the solution of all problems where solution is essential.

(ii) Industrial concerns may co-operate in the scientific solution of common difficulties, and this work, carried out for the good of all, may be financed on a co-operative basis, with or without Government assistance.

(iii) State Departments, Universities, Technical and Agricultural Colleges, and other organisations having similar facilities for research may be asked to conduct investigations of these economic problems.

(iv) Special Federal or State Laboratories or Institutes may be set up purely for the discussion of industrial problems.

It will be evident that these various lines of action are not by any means mutually exclusive. Several may operate simultaneously, and that either separately or on some conjoint basis.

A rapid survey is sufficient to show that each of the above methods has its peculiar limitations and disadvantages. Thus, when an industry is young and comparatively undeveloped, it is manifestly impossible for concerns each and severally to undertake the carrying out of all the technological research which is desirable to provide for a healthy growth of the industry. The financial burden is too heavy. To illustrate this point let me quote figures taken from industries associated with my own special subject. The United States of America possesses some highly flourishing electrical corporations. There is the Western Electric Company, a branch of the Western Telegraph Co., which has a huge department devoted to research and development. The staff numbers about 3000 and the annual cost of maintenance is over a million pounds sterling. Again there is the research laboratory of the General Electric Co. at Schnectady which costs in maintenance over a quarter of a million sterling per annum. The provision of such large laboratories is of course far beyond the means of any but the largest

firms. Yet it is to be noted that the firms mentioned find these vast research institutions advisable, indeed necessary, and a paying proposition. The research work is not limited to a pathological study of technical problems. The investigations carried out include very many researches in what is as much pure physics as anything done in the physical laboratories of Harvard or Yale Universities in America, or in the Cavendish Laboratory of the University of Cambridge. The interesting point is that these firms have no difficulty in finding useful practical applications for all the physical discoveries they make. Could there be a more striking proof of the value of co-operation between pure science and industry? As we are at present situated in Australia, we must be content for financial reasons that the research departments of commercial firms should be limited mainly to necessary work in investigating difficulties in routine processes, and to suggesting improvements in details, rather than extend their sphere to the devising of totally new methods.

We therefore turn to the second line of action, viz., co-operation between firms engaged in the same work. A practical difficulty is at once apparent. Firms which are rivals in trade must necessarily feel a certain jealousy towards one another. The heads of the firms may be, and often are, on the best of terms with one another, but directors and shareholders alike must doubt the advisability for their personal good of sharing information regarding their discoveries of improved procedure or methods. It may be possible to reduce this difficulty by getting firms belonging to the same industry to support a research laboratory operating almost as a separate institution and not attached mainly to one individual firm. Or alternatively, the research laboratory for a particular industry may be maintained by the joint financial support of individual firms subsidised by a definite Government grant on a pound for pound or similar basis. The financial support so given by the State is then to some extent a guarantee that results obtained under the scheme in the works of a particular firm are public property and available to all concerned. As a rule, however, such schemes are regarded with a certain amount of suspicion, and I doubt whether they have proved successful in many cases either as regard the quantity or the quality of the work accomplished. It is but fair to say that some industrial firms have taken a commendable national view of their position, and have done much to give help and to make knowledge available to kindred establishments.

We come now to the part which can be taken in this work by Universities, Colleges and State Departments. Take first the case of the educational institutions. Their interest in the matter is two-fold. It is their duty to train men who have the broad

general and the intensive specialised education necessary to enable them to do effective work as research physicist or research chemist attached to a particular industrial concern. These institutions are carrying out this work as thoroughly as the limited funds at their disposal will allow, and I think that Australian firms which have selected Australian graduates as their scientific experts have had little reason to complain of the ability and training of the men they have obtained. But if the Universities and Colleges are to go further than this, and conduct that research which is necessary for the development of industries and the improvement of industrial methods, a new order of things will be required. At present the laboratory provisions are inadequate for such work, the staffs are so fully engaged in teaching that there is too little time for important researches, and the University men have insufficient opportunity for getting that close insight into works practice which is desirable if their investigations are to bear much fruit in industry. Research, if it is to be of value, cannot be relegated to occasional intervals of freedom from other and engrossing duties. It must be taken seriously and such time given to it as allows the investigator to settle down to his work, and to have the details of the inquiry ever in his mind. The same difficulty confronts those in the Public Service. Apart altogether from the endless files and routine operations, there are so many calls on one's time for the dissemination of knowledge of long established facts that comparatively little time may be left for serious research. This is not as it should be. There are in the Public Services of the Australian States men of outstanding ability, who would be able to do much valuable work if they could only in some measure be liberated from a multitude of administrative detail, which might equally well be discharged by someone without the same scientific training. So long as the present system obtains, so long must many Government departments remain bureaux for the issue of information rather than organisations for the acquisition of fresh knowledge. In my opinion there is another factor which has seriously militated against certain Government scientific departments being the highly effective bodies they might and should be. That is the promotion of individuals on account of seniority alone. A man may be an excellent officer in a particular post, but that does not necessarily mean that he should be advanced to a senior position when such becomes vacant. The essential test should always be whether the junior officer has the qualifications to enable him to discharge efficiently the duties of the higher office. If he has, then his experience in the department will undoubtedly make him peculiarly fitted for promotion. A junior officer who has done meritorious work is deserving of reward, and, if he has the necessary qualifications, the natural reward is promotion in grade and pay. But, if he has not the

training and other qualifications desirable in the higher grade, the reward of faithful service and of increased value from experience gained should be higher pay in the same post. Promotion to new duties makes a heavy strain on the best man. Promotion of an unqualified man means either endless worry to the unfortunate being if he is a conscientious individual, or, if he is not conscientious, then the adoption of a "trust to luck" attitude which spells disaster to individual, department, State, and to the fair name of science. In Universities promotion from the position of demonstrator to assistant or lecturer and to professor, is made strictly upon qualifications, and the fact that most people have to move from one institution to another for promotion is proof that seniority is but lightly considered. Yet even the junior assistant in a University has undergone a long and expensive pro- course of training which may in the end carry him far in his pro- fession. I recognise that the public services are in many of their branches recruited by the admission of youths direct from intermedi- ate and secondary schools, but all will agree that such admission of juniors and promotion mainly by seniority must spell disaster, if ample facilities for later training are not granted. Western Australia, I am glad to say, is doing a great deal both in demanding a good standard of education in those taken into the professional branches of its Public Service and in giving facilities for further study. It would however be advantageous if this action were ex- tended and that it were copied in some other parts of the Common- wealth.

We come now to the fourth of the suggested lines of action, viz., the institution of special Federal or State laboratories for industrial research. In certain cases this is, I am convinced, the only solution of the problem. Yet I feel it should not be tried as the general solution. Central laboratories will cost about as much as the special development, equipping and staffing of exist- ing laboratories. It may be the best solution where investigations can be made equally well in any part of the Commonwealth or best in some one locality, and where the results there obtained will be equally applicable to all the States. It is the ideal solution where, in addition, no laboratories are as yet existent which have any facilities for carrying out the work. To hesitate to select one specialised laboratory for the work is merely to encourage each State to take up the research with the resultant loss due to avoidable overlapping. But to establish a special laboratory to carry out work which can be done as well in an existing labora- tory is waste. It is wasteful to take such action if some State Department has special facilities for making the investigations. It is at least undesirable to form a special Federal Laboratory for some work if that work could be carried out equally as well

by some University if given the same resources; particularly as the work, if associated with a University, would give perchance excellent opportunities for the training of senior and post graduate students.

In March, 1916, the Federal Government created a temporary Advisory Council of Science and Industry to prepare the way for the creation of a permanent Institute. The Act to establish the Institute was passed in 1920, and the Director was appointed in the following year. During the past few years investigations have been made into certain agricultural, pastoral, and industrial problems, and in a few cases the Institute in its work has been aided financially by certain of the States. In some cases the Institute has co-operated with State Departments or Universities, but the majority of the industrial investigations have been carried out by a staff of special research officers. Prior to the establishment of the permanent Institute there had been in each State Advisory Committees which reported to the central Advisory Council. The Act of 1920 provided for the establishment of similar committees, but no action has been taken under this clause, with the result that the former committees automatically lapsed. Likewise a provision in the Act for grants to encourage training in research has remained inoperative. These both appear to me to be regrettable omissions. It is essential for effective work that such a Federal institution should be in the closest possible touch with the leaders in industry and with the men of science in the individual States. Again the carrying out of industrial research is dependent on the training of research workers and their initiation into specialised problems by employment on minor problems. This has been recognised by the British Department of Scientific and Industrial Research which was created in 1915. For the year 1923-24 out of a vote of £277,000, no less than £41,000 was expended in grants for pure scientific research in Universities. The Carnegie Institution of Washington has likewise attempted to train research workers by having a graded system of graduate students, research associates and research officers. The Mellon Institute of Industrial Research in Pittsburg trains men for similar work. It operates on the system that every individual or company desiring attention directed to a particular problem must provide funds for a Fellowship to train a man for industrial research. Eighty-three Fellowships were thus in operation in the year 1923-24. Other national research organisations have made similar provisions for training investigators, and nothing but good has come from such provision.

As you are all aware, there is at present a move to reorganise the Federal Institute. A conference, called in May by the Prime Minister, has discussed proposals for the constitution of the Insti-

tute and for its programme of inquiry. These are now before the Federal Cabinet, and it is expected that a Bill will be introduced at an early date for the amendment of the Act of 1920 which laid down the original constitution of the Institute.

There are several matters which in my opinion are essential for the success of the reorganised Institute.

In the first place the various States should be allotted an important share in the direction of the Institute and in the planning of the research investigations. If advisory committees are formed in each State, such Committees will be able to assist in no small measure in assessing the relative importance of problems requiring solution in their respective States. The personnel of such Committees need not necessarily be made up mainly of those who are likely to engage in industrial research. Indeed it may be that such persons would be more apt to be biassed in favour of some particular branch of applied science than those who, while well versed in general science or in the needs of developing industries, look at the matter with less personal interest. These State Committees could then send representatives to form a central Federal Executive or Council. In my opinion it is essential that some such body, truly representative of all the States, should have definite executive as distinct from merely advisory functions; that, in fact, it should be in control of the scheme, subject of course to the decisions of the Federal Cabinet or Minister in Charge. As such Federal Councils can meet only three or four times a year a Chief Executive Officer would be necessary to carry out the decisions of the Council and to act in all urgent matters which may emerge between meetings.

In addition there will be required men who will organise and superintend the researches. It will be undesirable to overload the scheme at the outset with too many men whose function would be to direct research rather than to carry out the detailed investigations. At the same time a scheme should be adopted which will be capable of development and expansion as the work of the Institute justifies further expenditure. The Carnegie Institution of Washington conducts its inquiries in many great departments. Each is under the control of a scientific expert, a specialist who organises the research in his department and selects and supervises his research assistants. The allocation in due proportion between the several departments of the available funds of the Carnegie Institution lies largely in the control of a President, a man of sound scientific training and with considerable administrative ability. Could not something on similar lines be our goal in Australia? One might begin with two organisers of research, one a man with qualifications in natural science, the other in chemistry and physics or engineering. As time went on these duties

would be subdivided, such subdivision depending on the urgency of problems awaiting solution and upon the financial gain to our nation of work accomplished by the Institute or under its aegis. It might not be long until such branches as Agriculture, Entomology, Forestry, and Veterinary Science called for separate and individual treatment under the general direction of a special organiser.

When it is decided to take up a particular line of research I anticipate that the existing method will be followed of appointing an Advisory Committee of experts in the special subject of inquiry. In this way the actual investigators will be given the maximum amount of help and the various interests particularly concerned in the research will be kept in touch with its progress. Such a Committee of experts in consultation with the central Council will also be in a position to decide the best means of conducting the investigation. In many cases it may be necessary to do the work in a special laboratory of the Institute. In others, however, it should be possible to make use of existing State laboratories whether attached to Universities, Technical Colleges or Government Departments. Only by so avoiding duplication of laboratories will the scheme be financially efficient, and only by so making use wherever possible of State Institutions will the interest and helpful co-operation of the States be maintained. In some cases where the investigation has to be carried out on a full works scale it may be possible to carry it out in some industrial factory. Similarly it will often happen that some existing laboratory can at low cost be extended to enable it to deal with a particular problem, and in such instances it will surely be preferable to adopt this procedure rather than to spend a larger sum on equipping a special laboratory.

Here let me emphasise the fact that the most vital need we have at present in Australia is for more trained investigators. No scheme for benefitting industry through science can afford to ignore this fact. I have already pointed out that the British Department of Scientific and Industrial Research devotes about 15 per cent of its funds to grants in aid of research. In Australia at least 20 per cent of the available money should be set aside at the outset for this purpose. There are two reasons for adopting this course. I have already referred to one, viz. the necessity of training investigators. The second is no less important. One cannot always obtain by order the solution of a problem. If the Institute is going to initiate research only when difficulties in commerce and industry call for aid, then I am afraid the percentage of successes among the problems taken up may be low. As Sempronius was advised: "'Tis not in mortals to command success." There are however in Australia many qualified

investigators in scientific departments and institutions who, as a result of special training or other circumstances, have become interested in a particular line of inquiry. But, owing to lack of funds, the research lies untouched or makes little progress. I would suggest that if the Institute gave grants in aid of such investigations there would be a quick and abundant harvest. The Carnegie Trust for the Universities of Scotland has now made grants in this way for a quarter of a century and the results have been excellent. I am convinced that the effect in Australia of such a scheme would be no less beneficial.

There are some I know who argue that all the work of the Australian Institute, or at any rate by far the greater part of it, should be carried out in the Institute's own laboratories. They say that our University staffs have no time for research. I feel sure that time will be found if opportunity for the work is otherwise forthcoming. Moreover I say without fear of contradiction that the teaching staffs of our Australian Universities will never be in the proper position to give the best instruction to their students unless they are enabled through research to keep in the closest touch with the industries and commercial undertakings in our Commonwealth. Anything which is going to bring our University students, our young men and young women, into a knowledge of research methods is going to raise greatly the scientific standard in Australia. Sir J. J. Thompson has said "I think that every scientific worker should undergo a year's training in research, not merely because in many cases the business of his life would be research, but also because of the effect it has upon his mental development and character. I have had many opportunities of watching the change produced in men by a year's research. The results are striking. It increases a man's independence of thought, it increases his resource, it increases his critical power, and it increases his enthusiasm; in fact, it raises him from intellectual adolescence to intellectual manhood."

Much scientific work remains to be done here in Australia. Ours is a vast continent, the population is small, but the possibilities of future development in commerce and industry are enormous. Wisely directed these developments may make this fair land a great and prosperous possession for the British race. On the other hand, developments along faulty and ill-considered lines would lead to reverses, loss and ultimate disaster. Science can play an important part in guiding our destiny. May it be the work of every scientist in our Commonwealth to do his or her share that Australia may advance.

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